REPORT

OF

MANGANESE POISONING ENQUIRY COMMITTEE

MINISTRY OF LABOUR AND EMPLOYMENT

GOVERNMENT OF INDIA

1960

MANGANESE POISONING ENQUIRY COMMITTEE,
Ministry of Labour and Employment,
Government of India.

No. NEW DELHI, Dated 30-11-60.

From

Dr. M. L. Rawal,
Chairman,
Manganese Poisoning Enquiry Committee.

To

The Secretary to the Government of India,
Ministry of Labour and Employment,
New Delhi.

Dear Sir,

I have to refer to the Ministry's letter No. MI-41(74)/56, dated 3rd November, 1958, and to submit herewith the report of the Manganese Poisioning Enquiry Committee.

Yours faithfully,
M. L. Rawal
Chairman.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER I

The Manganese Poisoning Enquiry Committee was appointed by the Ministry of Labour and Employment, Government of India. The following constituted the Committee :

(1) Dr. M. L. Rawal, MBBS (Bombay), DPH, DIH (Eng.), Professor of Preventive & Social Medicine, B.J. Medical College, Ahmedabad 16. (Chairman)

(2) Dr. M. N. Rao, MBBS (Andhra), MPH, DPH (Harvard), FAPHA, Professor of Physiological & Industrial Hygiene, All-India Institute of Hygiene and Public Health, 110 Chittaranjan Avenue, Calcutta-12.

(3) Dr. N. H. Wadia, MD (Bombay), MRCP (London), Assistant Physician, In-Charge of the Department of Neurology, J. J. Hospital, Bombay.

(4) Dr. T. P. Niyogi, MB (Cal.), MRCP (Edin), DTM & H (L'Pool), Civil Surgeon, Jabalpur, Madhya Pradesh.

(5) Dr. M. N. Gupta, MBBS (Pb.), DPH (Lond.), DIH (Eng.), Deputy Chief Adviser Factories (Medical), Ministry of Labour & Employment, Government of India, New Delhi.

(6) Dr. M. K. Chakraborty, M.Sc. (Dacca), D. Phil. (Cal.), Assistant Director, Central Mining Research Station, Dhanbad.

(7) Dr. B. K. Sengupta, Junior Labour Inspector of Mines, Dhanbad.

The terms of reference of the Committee were as follows :

"A complete investigation of causation, extent, diagnosis and treatment of the different varieties of manganese poisoning found in the workers of the manganese mines in India and to advise on the preventive measures that may be enforced."

HISTORY OF MANGANESE POISONING AND THE FORMATION OF THE ENQUIRY COMMITTEE

In February 1956, the Mine Manager of a manganese mine, situated in the district of Chhindwara, Madhya Pradesh, visited the Office of the Regional Inspector of Mines, Chhindwara and met Dr. B. K. Sengupta, the then Junior Labour Inspector of Mines, posted at Chhindwara. The purpose of the visit was to know whether he could dispense with the services of some of the underground workers employed in his mine, who, according to him, showed definite signs of mental imbalance and whose continued presence in the mine could be unsafe not only to themselves but also to their co-workers. He wanted to know if the Department of Mines could help him in such action. It was suggested to him to send the patients to Nagpur Medical College Hospital or to the Civil Surgeon, Chhindwara for diagnosis.

The manager, as suggested, sent some of the patients to the Nagpur Medical College Hospital where they were admitted and kept for about a month under observation. The cases were diagnosed as "Shaking Palsy" and were recommended "rest". The Manager produced the discharge certificates for further instruction. As the diagnosis had nothing to do with the Manager's complaint, he was further requested to send the patients to the Civil Surgeon, Chhindwara, for observation and diagnosis.

Dr. T. P. Niyogi, the then Civil Surgeon, Chhindwara, examined these patients and suspected them to be cases of chronic manganese poisoning.

To coroborate the findings, a surprise inspection of the mine was made on the 2nd June, 1956, and it was found that dry drilling was being done on the floor and sometimes also on the sides and roof of the mine. While in the mine, three more cases were also found amongst the drillers manifesting similar symptoms. The manager was requested to send the above mentioned three cases also to Chhindwara Hospital for observation.

After a period of close observation, these seven cases were diagnosed by Dr. T. P. Niyogi as cases of chronic manganese poisoning. Those were the first cases of manganese poisoning reported in India. One of them, it may be added, had been earlier diagnosed as 'insane' by a local physician and kept for some time in Sausar Jail, Chhindwara district.

On 15-6-1956, the Junior Labour Inspector of Mines reported the matter to the Chief Inspector of Mines in India, through the Regional Inspector of Mines, Chhindwara. The Chief Inspector of Mines was requested to send Dr. M. L. Rawal, Inspector

of Mines (Medical), for a further detailed study of the cases in collaboration with the Chhindwara Hospital authorities. He visited Chhindwara on the 13th July, 1956, and examined some of the cases at Chhindwara Hospital. He was also of opinion that they were cases of manganese poisoning and submitted his report to the Chief Inspector of Mines in India, who forwarded the report to the Ministry of Labour with the request that a committee be appointed to investigate the matter. The Ministry agreed to the proposal.

SCOPE OF ENQUIRY

The terms of reference of the Committee were very wide. They include complete investigation of the causation, extent, diagnosis and treatment of the different varieties of manganese poisoning and advice on the preventive measures that may be enforced.

The manganese mining industry is very extensively spread all over the country with 619 mines in 1958. As it was not posisble to visit even a fair number of these mines, the Committee had to keep contented with investigation in twelve mines only. As most of the industry is concentrated in States of Bombay and Madhya Pradesh, the Committee decided to take 4 and 5 mines from these states respectively. One mine each from the State of Gujerat, Orissa and Mysore was also included in order to find any difference in the causation of the disease due to the difference in the composition of the ore, and the living condition of the people and to get a cross sectional view of the mines and workers. To observe the effect of manganese fumes on the human system, the Committee selected a ferro-manganese plant also. In view of the fact that the original cases of manganese poisoning were reported amongst underground workers, the Committee decided to include as many such mines as possible with underground working. Out of a total number of 64,936 persons employed in the manganese mining industry (1958), the Committee could examine only 1,132 workers—drillers, driller-helpers, shotfirers, miners, loaders, heavy machinery operators, ore crushers, supervisory staff, etc., both of underground and surface were selected for such investigation.

The investigations were carried out in the field, in laboratories and in hospitals.

In all, 1,132 workers were examined at the work site and only 9 select workers who showed signs of manganese poisoning were admitted to hospital for detailed investigations. (*Vide* Table I).

TABLE I

Code No. of Mine	Below ground[1] / Above ground	Average daily employment in 1958			Number of workers examined			Percentage of workers examined to the total employed		
		Below ground	Above ground (including open workings)	Total	Below ground	Above ground	Total	Below ground[2]	Above ground	Total
1	BG+S	270	416	686	70	17	87	25·93	4·09	12·68
2	OW+S=AG	—	434	434	14	45	59	?	10·37	13·59
3	Do.	—	815	815	13	91	104	?	11·17	12·76
4	Do.	—	865	865	—	100	100	—	11·56	11·56
5	BG+OW+S	12	339	351	53	47	100	?	7·36	15·36
6	Do.	17	939	956	19	81	100	?	8·63	10·46
7	Do.	711	2,227	2,938	116	14	130	16·32	0·63	4·42
8	OW+S	—	1,797	1,797	—	104	104	—	5·79	5·79
9	BG+OW+S	503	1,244	1,747	105	—	105	20·87	—	6·01
10	Do.	59	669	728	34	16	50	57·63	23·92	6·87
11	OW+S	—	1,541	1,541	—	92	92	—	5·97	5·97
12	OW+S	—	1,211	1,211	—	101	101	—	8·34	8·34

1. BG=Below ground.
   OW=Open workings
   S=Surface
   AG=Above ground, open workings and surface.

2. The absence of employment under ground is either due to incorrect reporting of return or because the sample was taken in 1959.

The field investigation included a complete medical and occupational history, clinical, haematological and radiological examinations.

Environmental studies on the spot included an assessment of the dust hazard and the thermal environment. Further examination of samples of dust and water were done at laboratories in Nagpur and Dhanbad.

Animal experiments were carried out in the Jabalpur Medical College.

Complete hospital investigations were done at the Department of Neurology, J.J. Hospital, Bombay.

Though the Committee was appointed by the Government in November 1958, it could not meet for the first time till the middle of June, 1959, on account of organizational difficulties. The Committee had sixteen meetings in all.

CHAPTER II

THE MANGANESE MINING INDUSTRY

1. *Manganese Ores in General*

Manganese, a reddish grey metal, is comparatively softer than iron, but is hard and brittle if it contains carbon. Its specific gravity is 7.2, atomic weight 54.93, atomic number 25, melting point 1,260°C and boiling point 1,900°C.

Manganese does not occur in nature as free metal. When silicate ores of manganese are decomposed by surface water, as in tropical weathering, manganese separates out as a manganese compound-carbonate, oxide or hydroxide. In India, the ores of most of the manganese mines fall under this category.

The important manganese ores, as found in nature, are as follows :

Pyrolusite	MnO_2 is a soft grey-black ore with a manganese content of 63·2% in pure state and specific gravity of 4·8.
Psilomelane	Containing 45—60% manganese in colloidal form of MnO_2. Its specific gravity is 3·7 to 4·7 and is relatively hard.
Braunite	Mn_2O_3, $MnSiO_3$ contains 62% of manganese, is hard with specific gravity of 4·8. Its silica content may be as high as 8—10%.
Manganite	Mn_2O_3, H_2O—contains 62·4% of manganese, dark grey in colour, moderately hard, specific gravity 4·2 to 4·4.
Hausmannite	Mn_3O_4—It is brown to black in colour, hard and has a specific gravity of 4·8
Rhodonite	$MnSiO_3$—contains 42 per cent manganese.

Besides the well-defined ores of above compositions there are others whose compositions are variable, *e.g.,* Manganiferrous iron ores, 'wad' or 'bog manganese' etc.

The composition of manganese ores shows wide variability, specially in the ratio of manganese and iron contents. As most

of the manganese ores are used for metallurgical purposes, they are classified on the basis of manganese content and the type of ferro-alloy for which they are to be used, *e.g.*

(*a*) Manganese ores containing manganese above 35% are suitable for manufacture of ferro-manganese of high or low grade.

(*b*) Ferruginous manganese ores or spiegel ores which contain 10–35% manganese and may be used for spiegeleisen.

(*c*) Manganiferrous iron ores––with a manganese content of 5–10% are used for the manufacture of manganiferrous pig iron.

II. *Manganese Ores in India*

Manganese is a key metal in industrial age used both in ferrous and non-ferrous industries. The demand for this metal by industrial countries is, therefore, very high. India has one of the richest manganese ore deposits in the world estimated at more than a hundred and fifty million tons. Not only has India got an important export market for manganese but the indigenous demand for manganese is constantly on the increase with each of the National Five Year Plans.

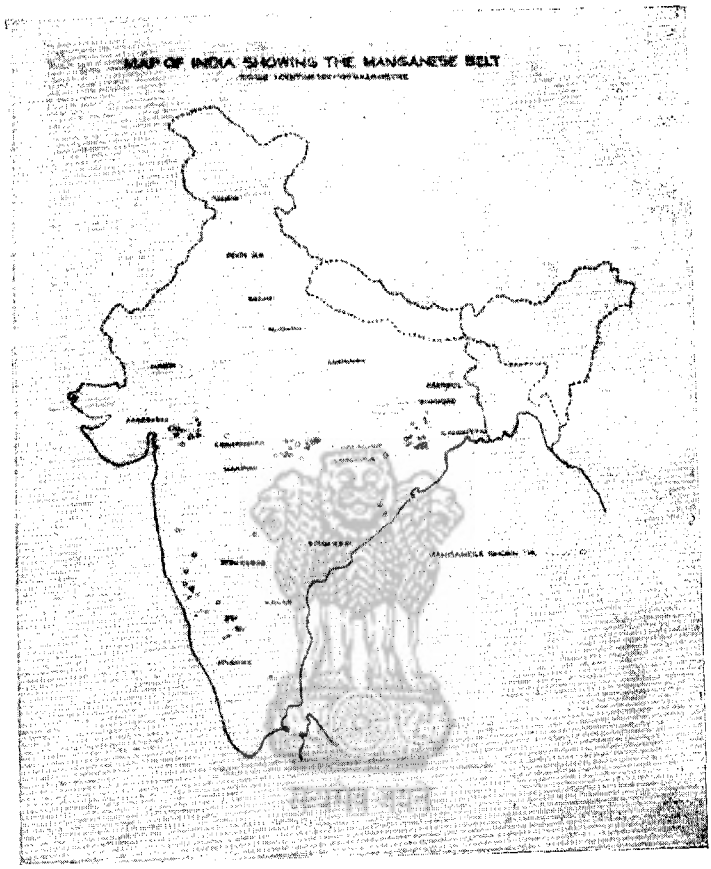
Narayanan et al (1959) have reviewed manganese mining in India and the following are relevant abstracts :

Manganese deposits in India are mainly limited to the States of Madhya Pradesh, Bombay, Orissa, Mysore, Andhra, Bihar and Rajasthan. Figure I gives an idea of the location of various deposits in India.

Manganese ores in areas which were in Madhya Pradesh prior to 1957, and which make up nearly 50% of Indian production, are usually associated with a rock series termed 'gondites'. These are manganiferrous sediments of Archaen Age, which by undergoing intense metamorphism have given rise to the ore deposits having braunite as the chief mineral along with smaller amounts of hollandite, sitaparite, etc. With long weathering these minerals as well as the silicates like the spessartite and Rhodonite have been altered in some places to Psilomelane, Pyrolusite, etc., as secondary deposits. In some areas in Nagpur and Chhindwara, low grade manganese ores are also found along with crystalline limestone of Archaen Age.

In Kandri-Mansar area the deposits are covered by muscovite schist. In Tirodi area, the lenticular manganese deposits are enclosed between a biotite paragneiss and silimanite bearing

Fig. I



muscovite schist. Manganese ores in Madhya Pradesh are characterised by their hard, lumpy and compact nature.

In undivided Bombay state the manganese deposits are mostly in Panch Mahal and North Kanara districts with smaller deposits in Baroda and Belgaum. The ore consists of psilomelane, braunite and pyrolusite. Phosphorus content is usually high but iron is within required limits. Free silica in the shape of quartz injections are encountered very often in the manganese ore body itself or even at the wall rocks.

Of the numerous deposits of manganese ores in Mysore, those at Sandur are the biggest. Iron content of this ore is high but phosphorus content is low. The ore consists mostly of psilomelane with smaller amounts of pyrolusite and manganite.

Table II gives an idea of the composition of the ores in the mines visited by this Committee in different parts of India. (*Vide* page 14).

The above details about the occurrence of manganese ores and the nature of their composition give an idea about the various materials a miner is likely to encounter in course of his work in the mine.

III. *The Manganese Miner in India*

In reviewing the statistics about manganese miners in India, it may be borne in mind that till about the time of Independence, the available statistics, *i.e.* the decennial reports of the Chief Inspector of Mines included data on mines in British India only including area like British Baluchistan and Santal Parganas, thus excluding important mines in Mysore and Rajasthan. Relevant comparable data only are presented in charts below.

(*a*) *Employment Statistics* : As can be seen from Figure II, the number of manganese mines operating in India have been widely fluctuating.

Employment in all Indian mines was generally on the increase since 1926 (*see* Figure III).

In 1958, the latest year for which figures are available, the average daily employment in all mines was 64-936. The employment in the manganese mines, however, was fluctuating markedly. In 1926, there were about 30,000 employees in manganese mines and from 1926 onwards when the economic depression started, the employment figures dropped to as low as 2,274 in 1933. In 1932, a very large number of manganese mines were closed down as they were uneconomical to run. As the country

Fig. II.

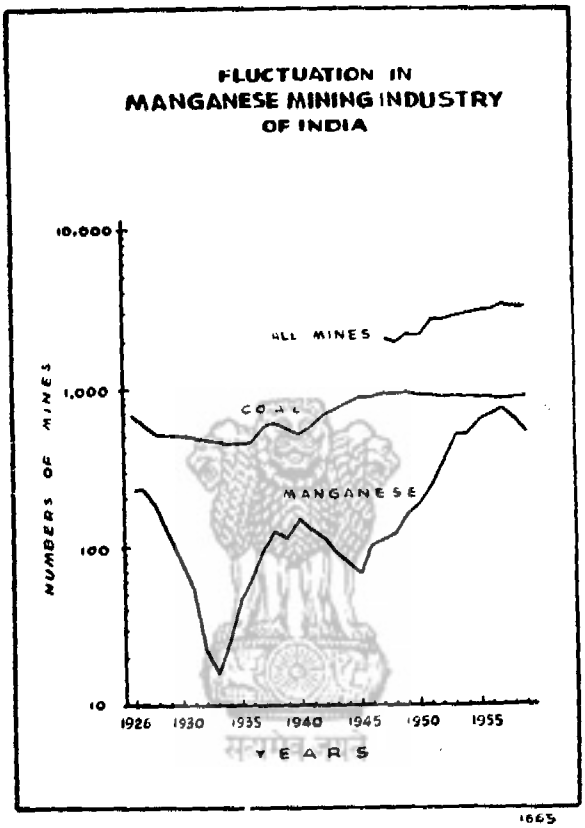

FLUCTUATION IN
MANGANESE MINING INDUSTRY
OF INDIA
10,000
1,000
100
10
NUMBERS OF MINES
ALL MINES
COAL
MANGANESE
1926
1930
1935
1940
1945
1950
1955
YEARS
1665

Fig. III.

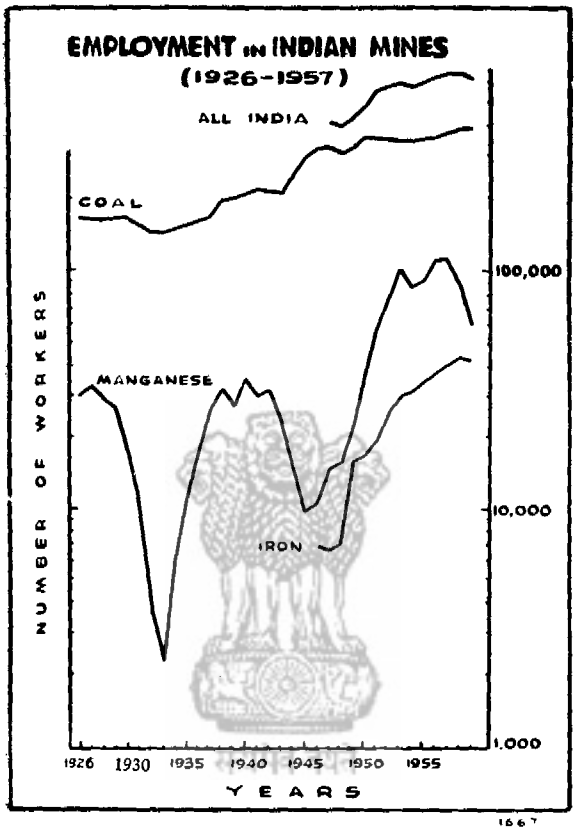

EMPLOYMENT in INDIAN MINES
(1926-1957)
ALL INDIA
COAL
MANGANESE
IRON
NUMBER OF WORKERS
100,000
10,000
1,000
1926
1930
1935
1940
1945
1950
1955
YEARS
1567

Fig. IV.

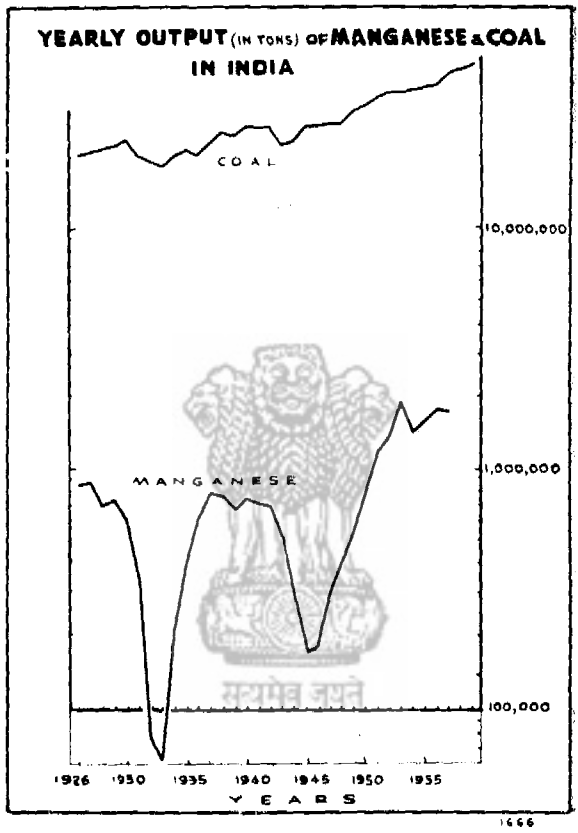

YEARLY OUTPUT (IN TONS) OF MANGANESE & COAL
IN INDIA
COAL
MANGANESE
10,000,000
1,000,000
100,000
1926
1930
1935
1940
1945
1950
1955
YEARS
1666

Fig. V.

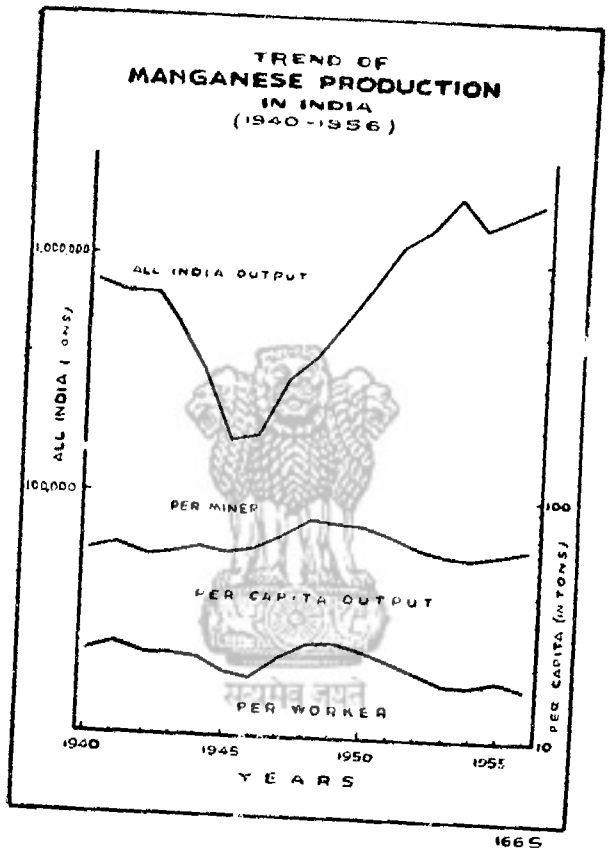

TREND OF
MANGANESE PRODUCTION
IN INDIA
(1940-1956)
1,000,000
100,000
ALL INDIA (TONS)
ALL INDIA OUTPUT
PER MINER
PER CAPITA OUTPUT
PER WORKER
100
10
PER CAPITA (IN TONS)
1940
1945
1950
1955
YEARS
सत्यमेव जयते
1665

TABLE II

Percentage Composition of Manganese Ore in the Mines Visited by the Committee

Code No. of the Mine	Manganese		Phosphorus		Silica		Iron		Free silica	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
1.										0·27
2.	45·62	52·30	0·12	0·33	7·50	12·78	4·75	6·05		
3. }	40·00	50·00	0·06	0·25	5·00	14·00	5·00	12·00	0·13	15·99
4. }										
5.										10·24
6.									0·24	1·38
7.	44·50	50·00		0·26	5·96	11·37	5·03	6·63	0·18	66·02
8.									5·54	89·82
9.									5·16	28·04
10.									5·16	28·04
11.	27·00	48·00	0·71	0·72	6·62	15·12	5·96	17·24	0·97	0·99
12.	38·00	40·00	0·03	0·05	2·00	3·00	16·00	18·00	1·44	3·26

NB : (*i*) Source—Data from the mine managements and Governmental sources.
(*ii*) Percentage analysis from settled dust samples.

recovered from economic depression, the employment in manganese mines came back to the pre-depression level by 1937. Till 1942, the employment was around 30,000 after which there was again a downward trend till 1945 when employment was less than 10,000 (9,580 in 1945). From 1945 onward there was a steady and steep increase up to 1953, the maximum being 1,10,214 in 1957 with minor changes in between.

The yearly output of manganese ore fluctuated correspondingly with the labour employed (Figure IV). Before the depression about 8,00,000 tons of ore was raised annually (8,57,099 tons in 1926) while in 1933 the output was as low as 53,240 tons.

By about 1937, the pre-depression output was reached and maintained for a few years, to drop again by 1945 when the annual output was only 1,73,772 tons. After 1945, there was a steep rise in the annual output which stood at nearly 2 million tons in 1957 (*vide* Figure V).

In spite of the war-time low production, it is obvious that the annual output per worker (about 20 tons) and the per capita output per miner (around 60 tons) is fairly constant. However, the per capita production is seen to rise significantly after Independence during the years 1948-49-50.

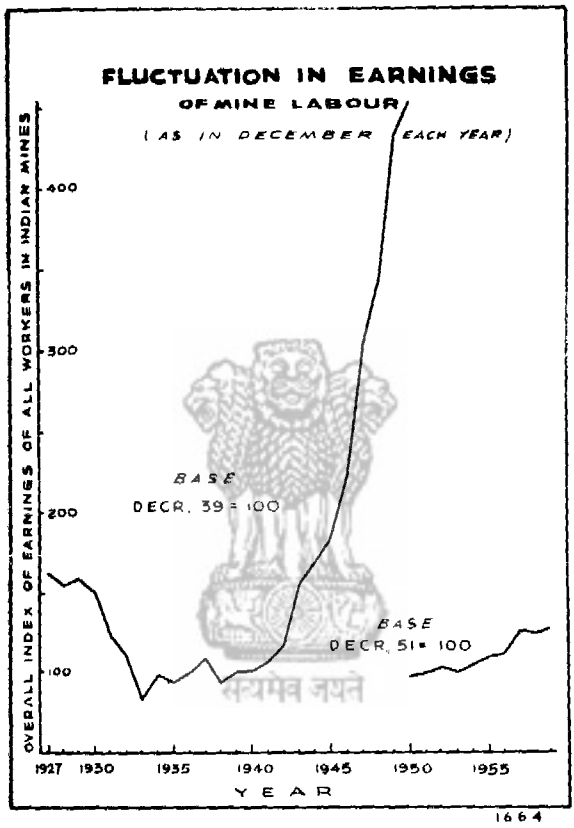
This marked fluctuation in the labour employed, unlike in other mining, reflects to a certain extent the dependence of manganese mining industry in India on international events. The sudden spurt in employment in manganese mines after World War II is perhaps attributable to stock piling in certain international markets and the growth of iron and steel industry all over the world.

(*b*) *Labour Earnings* : There are fairly reliable statistics available of the average daily earnings of manganese mine workers in India since 1927. The figures of Madhya Pradesh are given as indicating the general trends.

Figure VI represents the usual earnings computed on a weightage basis of the individual earnings of the foremen, miners, skilled and unskilled workers, underground and surface, and at the open workings.

There has been so much fluctuation in earnings and cost of living index that data in absolute terms would not be of much use. For example, in 1926 an underground miner was earning 0-14-0 per day, and during the depression years and thereafter as low as 0-6-0 per day. In the peak production years of 1956 onwards he was earning around Rs. 2/8/- per day. There is no

Fig. VI.


FLUCTUATION IN EARNINGS
OF MINE LABOUR
(AS IN DECEMBER EACH YEAR)
OVERALL INDEX OF EARNINGS OF ALL WORKERS IN INDIAN MINES
400
300
200
100
BASE
DECR. 39 = 100
BASE
DECR. 51 = 100
1927
1930
1935
1940
1945
1950
1955
YEAR
1664

indication, however, that the earnings of the manganese workers are in any way markedly different from those of the other miners in India.

There has been no scientific record of the health statistics of the manganese miner except the statistics on accidents, maintenance of which is compulsory by law. The fatality rates in manganese mining have been very low in comparison to those of coal and other mines. The number of deaths per 10,000 persons employed was never more than five except during the worst depression years, 1931 to 1933. During the post-depression period and after, there were only 2 or 3 deaths per year per 10,000 workers compared to an all-mine figure of 10 to 15.

The relative safety of manganese mining operations is reflected even more markedly from the trend of serious accidents, *viz.*, accidents involving stoppage of work for three weeks or over. After 1947, there has been a very sharp increase in serious accidents in both coal and other mines with a peak around 1954. In 1954, there were 84 serious accidents for 10,000 people employed in coal mines and about 71.6 per 10,000 employed in other mines. These figures compare very favourably with 15.7 serious accidents per 10,000 employed in manganese mines for the same year.

CHAPTER III

MANGANESE MINER AND HIS ENVIRONMENT

In assessing possible risks to health by any occupation, the correct approach will be to take into consideration the total health of man and assess the particular part played by his occupation. The Committee, therefore, while concentrating on manganese intoxication, had considered it necessary to study also his living and working environment.

I. *Living Environment*

(A) *Housing* : The workers in the mines were mainly housed in mining settlements owned by the management. A variable number of workers, however, were indigenous labour from the surrounding villages. Occasionally the Committee did come across amongst them instances where the mining occupation was familiar. Though immigrant labour was the rule, provision of housing colonies near the mines had given rise to a fair percentage of these workers living with their families.

The houses were not always of a high standard but they were comparable favourably to the poor neighbourhood housing.

(B) *Public Health* :

(*i*) *Water Supply* : Filtered water supply was practically non-existent in any of the mines visited and the common source of water was the open well or a nearby stream. From the outpatient statistics of sickness from the mines hospitals, there seems to be no obviously excessive incidence of water-borne diseases.

TABLE III

Manganese Content of Drinking water at the various Sources

Code No. of the Mine	Date of collection of sample	No. of water sources analysed	Range of manganese content in mg. per litre
1.	3-8-60	—	0·01 to 0·05
2.	31-8-60	—	0·04 to 0·05
3.	—	—	—
4.	14-9-59	5	0·06 to 0·16
5.	18-11-59	4	0·03 to 0·06
6.	20-11-59	4	0·02 to 0·04
7.	14-1-60	2	0·05 to 0·16
8.	19-3-60	3	0·07 to 0·21
9.	22-3-60	2	Nil to 0·11
10.	23-3-60	1	0·7
11.	10-3-50	1	Nil

As water arrives at the sources after percolation through the neighbouring manganese-bearing strata, the drinking water was analysed for its manganese content. The above Table III summarises the results obtained.

(*ii*) *Waste disposal* : Though the general sanitation could be very much improved, the workers seemed to be adjusted to a life that they are accustomed to in villages. Except in a few mines, there were no methodical waste disposal systems. The usual practice was indiscriminate defaecation in the open fields.

Fly breeding was a general feature. Though mosquito nuisance was encountered, the Committee did not find much evidence of mosquito-borne diseases like malaria or filaria.

(C) *Food and Dietary Habits* : Food and dietary habits of the workers were enquired into but no prolonged diet and nutrition surveys could be attempted. There was evidence of variance of dietary habits from mine to mine and also in the same mine itself depending on the different districts the workers came from. A general impression gained was that the diet was not a fully balanced one. The animal protein content of their diet was in general very low. Surprisingly in the majority of the mines, the vegetable and the milk content of the diet were very much lower than expected in a population group of this type living in rural environments.

As there is a controversy with regard to the possible etiological implication of Kesari dal in manganese poisoning, a specific enquiry was made about the intake of this item of food by the workers. In endemic areas of lathyrism like Rewa and other districts of Madhya Pradesh, Kesari dal either whole or husked is taken in fair amounts over long periods in the year. Some workers in Mines 9 and 10 located in Balaghat District gave histories of habitual Kesari dal intake. They came from the Seoni area. In Mine 1 where manganese poisoning cases were first detected, the dietary habits of the positive cases were gone into greater detail and it was found that Kesari dal did not form an item of food at all. Surprisingly, theirs was a simple diet of starchy foods like rice and potatoes.

(D) *Welfare Activities* : In addition to the statutory obligation, the mine managements in general provided suitable welfare measures. For instance, a medical out-patient department and varying degrees of subsidies for some of the foodstuffs were fairly common features in almost all the mines. Recreation facilities in general were not being utilised by all the workers to the extent provided for.

II. *Working Environment*

(A) *General* : Mining operations are generally dusty, irrespective of the materials mined. The extent and nature of this dustiness depend on many factors : the type of the mining operations, the type of the geological strata being worked on, the degree of mechanisation, the ventilation and dust control measures, etc. Any mine dust irrespective of its composition is a health hazard if inhaled in sufficient amounts over a period of time. If the dust happens to be of a type affecting the lungs not only as an inert foreign body but chemically absorbed, the dust hazard would be a more serious one. Manganese dust like any other metalliferous dust has the potential of being absorbed into the tissue fluids and causing a specific occupational disease—"Manganism".

As the Committee's assignment was to investigate the causation of Manganism, it was considered essential to conduct simultaneous dust and ventilation surveys to assess the extent of dustiness the manganese miner is exposed to.

(B) *Dust Surveys* :

(*i*) *Sampling* :

(*a*) *Sampling Technique* :

(1) *For Manganese Content* : Air samples for assessment of manganese dust may be collected in various ways. The final selection of the sampling instrument depends on its availability, volume of air to be sampled and the power supply. An Electrostatic sampler or a Greenburg Smith Impinger would have been very good for collection of sizeable sample in a short period. But not all the mines visited had underground electrical connections available for running these sampling equipments. So it was decided to use a Midget Impinger for the purpose of dust sampling. The period of sampling is decided upon by the dustiness of the operation. After collection, the samples are taken to the laboratory where they are analysed for their manganese content.

(2) *For dust concentration and size* : The Midget Impinger sample could also be used for dust count and size frequency analysis. But the sample being in a liquid medium needs be treated quickly. All the samples collected in the remote mines could not be transported immediately to the laboratory and so it was thought desirable to take separate samples by using a thermal precipitator. Samples collected by this instrument can be analysed a few days later without affecting precision. Moreover, this instrument has a high sampling efficiency for the dust of respirable sizes.

(*b*) *Sampling Points* : For both the above procedures, the sampling points were the same. A general survey of each of the mines was made in advance and the number and location of the sampling points determined to give a representative and a collective picture. The chief operations in the manganese mine which produce dust are : (1) drilling holes and blasting, (2) loading, and (3) screening. Air samples were, therefore, collected during all these operations and analysed for their manganese content and size distribution, etc.

(*ii*) *Analysis* :

(*a*) *Manganese Content*

(1) *Method* : The standard periodate method (Goldman and Jacob, 1953) for the estimation of manganese in the dust sample was used.

The dust sample collected by the Midget Impinger is treated with sulphuric acid for digestion into sulphate and nitric acid for oxidising and removal of any organic matter. After removal of the nitric acid, the manganese sulphate is treated with phosphoric acid and potassium periodate for conversion to permanganate. The intensity of the permanganate so developed is then estimated colorimetrically from a standard curve.

(2) The results of samples are summarised below :

TABLE IV

Manganese Concentration in the Environmental Air

Code No. of Mine	Type of the Mine	Mining Operation	Manganese in Mg/M3 air (range given in cases of wide variation)
1.	Underground	Wet Drilling	0·6 to 1·7
		Dry Drilling	25·4 to 361·8
		Loading	1·1
2.	Open cast	Dry Drilling	45·2 to 48·0
3.	Open cast	Wet Drilling	0·4
		Dry Drilling	34·5 to 35·3
4.	Open cast	Wet Drilling	1·1
		Dry Drilling	4·7 to 4·9
5.	Underground	Wet Drilling	4·6 to 5·2
		Dry Drilling	90·4 to 94·3
		Screening	0·7 to 4·9

TABLE IV—*contd.*

1	2	3	4
6.	Underground	Wet Drilling	0·4 to 2·1
		Dry Drilling	25·3 to 30·4
7.	Underground (a wet mine)	Wet Drilling	1·0 to 1·6
		Dry Drilling	1·9 to 23·4
8.	Open cast	Wet Drilling	0·9
		Dry Drilling	4·1 to 12·4
		Rock Crushing	1·3
9.	Underground	Wet Drilling	2·3
		Dry Drilling	8·5
		Loading	2·5
10.	Underground	Dry Drilling	21·2
		Loading	0·9 to 1·7
11.	Open cast	Dry Drilling	11·8 to 12·3
		Screening	12·3
		Ferromanganese Plant	0·8 to 16·2
12.	Open cast	Dry Drilling	2·0 to 2·8

(*b*) *Dust Concentartion and Size*

(1) *Method* : The manganese content of the air-borne dust gives an idea of the potentiality of manganese hazard due to inhalation of dust in the air. The extent of this specific hazard, as also that of any concurrent hazard of pneumoconiosis can be scientifically assessed by the number and size distribution of the air-borne particulate matter. Heavier particles settle faster as per Stoke's law and particles of about the size 5 micron and less mostly constitute the respiratory hazard. The thermal precipitator used in the study has its maximum efficiency in this hazardous size distribution. The number of particles deposited on the cover glasses are counted under a microscope and expressed in millions per cubic foot of air sample collected.

The dust concentration alone cannot be expected always to give a complete assessment of the dust hazard. As the hazard is greater with inhalation of the smaller size particles of respirable dust, a size frequency distribution is also of importance. In expressing this distribution the size characteristic of a non-uniform dust may be better had by size frequency curve which is usually skew. Such size distribution data may be plotted with advantage on logarithmic probability paper and the skewness expressed as geometric mean and its deviation.

(2) The results are given in Table V following.

TABLE V

Particulate Size and Concentration of Airborne Dust of Different Manganese Mines

Code No. of Mine	Mining operation	Concentration in million particles per cubic foot*	Size (Geometric mean in microns)*	Geometric Deviation in microns*
1.	Wet Drilling	149 (464)	0·71 (1·05)	1·95 (2·28)
	Dry Drilling	331 (1030)	0·88 (1·05)	1·60 (2·14)
	Loading	108	0·88	1·63
2.	Dry Dilling	269	0·80	1·76
3.	Dry Drilling	258	1·32	2·03
4.	Dry Drilling	25	0·74	2·06
5.	Dry Drilling	235	1·15	2·53
	Screening	33	2·28	2·85
6.	Dry Drilling	37 (62)	1·14 (1·84)	3·0
7.	Dry Drilling	21 (107)	0·51 (0·80)	1·78 (2·98)
		17	0·58	2·70
8.	Dry Drilling	28 (153)	0·75 (1·09)	2·08 (2·27)
	Crushing	5	1·08	2·07
9.	Dry Drilling	98	0·93	2·23
	Wet Drilling	10	0·93	2·23
	Rock Drilling (dry)	278	1·43	2·10
	Chute	4	—	—

*Maximum values in brackets.

TABLE V—*contd.*

(1)	(2)	(3)	(4)	(5)
10.	Dry Drilling	138	0·45	2·14
	Wet Drilling	5	—	—
11.	(*a*) Dry Drilling	39 (93)	1·01 (1·04)	2·58 (2·88)
	Screening	585	1·18	2·62
	(*b*) Dry Drilling	48 (86)	0·82 (1·01)	2·14 (3·56)
12.	—	25 (44)	0·45 (0·50)	2·00 (2·14)

*Maximum values in brackets.

One can see clearly from Tables IV and V the very high dust concentration and manganese content of the respirable air during dry drilling operations compared to wet drilling.

(C) *Ventilation Survey*

The deepest manganese mine was mine No. 1 which was 700 feet deep. None of the mines had any artificial ventilation systems. They were all dependent on natural ventilation through shafts and winzes. To assess the extent of this natural ventilation, air velocity measurements were taken at select points in all the underground mines. The air movement underground was found so low that standard field anemometers could not be used. Therefore, a blue kata thermometer was used as a low velocity anemometer.

Practically, in all mines there was no air movement at the ore face. The Kata thermometer uniformly recorded an air velocity not more than 30 feet per minute, at the blind ends, except in one working face in one mine where 60 feet per minute was recorded. The still air conditions were uncomfortable. At the galleries also there were still air conditions prevailing except in two instances near the shaft where 100 feet per minute was recorded. It may therefore be concluded that the existing ventilation systems are poor in the underground mines visited by this Committee.

The air velocities at the surface, as to be expected, were ranging from 100 to 500 feet per minute.

As all the mines depend on natural ventilation, which in turn depends largely on the thermal gradient with the surface temperature, the conditions of environmental warmth were also recorded. The maximum recorded was in two mines, *viz.*, 85.5 Effective Temperature uniformly in Mine No. 1 and in one work face in Mine No. 7. The surface temperature in both the cases was about 91.0° F—a relatively narrow range of temperature fluctuation for an effective natural ventilation system to work. Unlike in Mine No. 7 which is a well organised one, in Mine No. 1, the working conditions were uniformly uncomfortable

CHAPTER IV

MANGANESE INTOXICATION—CLINICAL MANIFESTATIONS

We examined in all 1,132 workers from 12 different mines. The selection of the workers provided us with a fair cross section of the various mining populations working under different environmental and climatic conditions. At the same time, we had the opportunity of examining all who were even remotely thought to have any manifestations of the disease. Anybody with any neurological or other disease, regardless of what it was, was examined by us to make certain that it could not possibly be due to the industrial hazard of manganese.

The deleterious effects of manganese seem to be confined to the nervous and respiratory systems only. Some unusual changes were noted in the oral mucosa which were thought to be due to mere contact with the metallic dust. A few general symptoms like asthenia, anorexia, body pains, cramps, etc. were also complained of. Haematological examination revealed some interesting findings.

The general examination of the patient showed no striking abnormalities but the general health, the abnormal gums, oral pigmentation and the cracked feet need some mention.

General Health : The general health of the workers varied from mine to mine and in different regions. It mostly depended on the circumstances under which they lived rather than the actual contact with the dust.

The following Table gives an idea of the common symptoms complained by the miners:

TABLE VI

General Complaints

Symptoms	Total	Percentage
Fatigue	277	24·47
Lumbar Pain	218	19·26
Anorexia	164	14·49
Insomnia	56	4·95
Muscle Cramps	54	4·77
Impotence	37	3·27
Mental Irritability	30	2·65

Oral Pigmentation : In some of the mines we noticed certain pigmentary changes in the oral mucosa. The pigmentation was found in any category of worker, in either underground or open cast mines. Most individuals were perfectly healthy otherwise. These changes were, however, more commonly found under unhygienic oral conditions. The pigmentation was on the gums, hard palate and in a small number of individuals also on the soft palate. The parts of the gum exposed to the external air seem to be most affected, the pigmentation ending in a sharp line of definition between the normal pink gum and the abnormal hypertrophied gum.

The colour of the pigment varied from dark black to slate grey, and was maximal on the outer side of the gum above the front teeth, and on the inner side near the molars. The pigmentation near the molars often continued on to the hard palate. The pigmentation on the hard palate was uniform, not raised and of slate grey to light grey colour. In a few workers slight pigmentation of the uvula and the adjacent soft palate was noticed. Here the pigmentation was brownish in colour and was laid down in three or four parallel lines along the breadth of the uvula along the mucous folds. At times it radiated "fanwise" from the base of the uvula on to the soft palate for about half to one cm.

The pigmentary changes were noticed as most striking in Mine No. 7 where otherwise the general health of the workers was good and apart from some respiratory manifestations, there was no evidence of manganese intoxication. The pigmentation was also noted in the workers of the Ferro-Manganese Plant visited by us.

The oral pigmentation cannot be called a manifestation of manganese intoxication, but is probably due to the direct effect of the metallic dust on the gum.

Cracked Feet : A number of workers showed unusual thickening of the soles of the feet with deep transverse cracks. These were seen in barefooted workers only and were believed to be due to the direct local effect of the dust on the skin. Similar changes were also observed in a few workers in the palms only.

Respiratory Complications (Pneumopathy) : The incidence of respiratory disease was high. The respiratory complications were mostly transitory episodes with little permanent damage to the pulmonary tissues. Regardless of whether they worked in open cast or underground mines, a fair proportion of workers gave a history of previous episodes of acute pneumonia with severe cough, high fever, chest pain, breathlessness and at times

rusty sputum. Most of them stated that they were severely ill and had to be away from work for nearly three to four weeks, the temperature itself lasting for nearly a week. There were others who gave a history of milder pulmonary infection, often repeated several times over many years, which was suggestive of attacks of acute bronchitis. Such histories may not be entirely reliable enough to give a detailed statistical incidence of pulmonary infection in these mines, but the overall impression created was that chest complications were not an uncommon hazard of the manganese mining industry. This was amply corroborated by the various medical officers in the mines, who considered respiratory disease as the most common (or one of the most common) ailments that came under their treatment. 19% of workers gave a history suggestive of pneumonia and 39% of acute bronchitis. Our clinical examination revealed that 6.5 workers had chronic bronchitis. Chest complications were not limited to any special category of workers.

Chronic Manganese Poisoning : This condition essentially consists of neurological symptoms and signs, very often accompanied by general symptoms like anorexia, easy fatiguability, insomnia, etc.

There was no difficulty in recognising the clear-cut form of this disease, when both symptoms and signs, however, early, were present. However, in a largely illiterate and easily impressionable population of mine workers it became very difficult to sort out the borderline cases—specially those with only symptoms without any physical signs. Again, there was a small group of patients who had neurological manifestations which could not be classed as amongst those already known to other workers in the field. The question which arose, and which will be discussed in full later on, was how to classify these patients.

The classical cases were entirely restricted to the two underground mines (Mines Nos. 1 and 9) and that too, to the underground workers. The group of doubtful cases of intoxication was limited to Mine No. 1 where the more severe variety of manganese intoxication cases were detected. Out of 1,132 workers examined by us in 11 mines, and one Ferro-Manganese Plant, there were

(1) *Manganese Intoxication* (Classical cases)

(*a*) Mine No. 1—15 cases :

(i) Mild—4 cases (10, 16, 18, 19)
(ii) Moderate—4 cases (5, 9, 13, 14)
(iii) Severe—7 cases (1, 2, 3, 4, 6, 11, 15)

(*b*) Mine No. 9—13 cases :

(i) Mild—9 cases (797, 820, 821, 825, 845, 870, 879, 880, 889)

(ii) Moderate—1 case (883)

(iii) Severe—3 cases (878, 881, 884)

(2) *Doubtful cases*

(*a*) Mine No. 1—9 cases (12, 17, 20, 22, 23, 24, 43, 44, 45)

(*b*) Mine No. 9—Nil.

(3) *A group of neurological cases with manifestation other than classical manganism*

(*a*) Mine No. 1—1 case (8)

(*b*) Mine No. 9—2 cases (838, 847)

(*c*) Mine No. 10—4 cases (890, 891, 892, 893).

(1) *Manganese Intoxication* (Classical cases)

The workers affected by the condition were all males. Whilst not many female workers were examined, detailed enquiries made in each mine regarding any form of neurological disease amongst the female mining population brought forth no reports of such incidence. The only workers affected were all drillers except one who was a driller helper (Case No. 2). No cases were detected in the Ferro-Manganese Plant visited by us.

The period of exposure to the dust before the first symptoms appeared varied from worker to worker. In Mine No. 1 it was 6 months (Nos. 13 and 18) to 6 years (No. 3). In Mine No. 9 it was 7 months (No. 821) to 17 years (No. 883). Of course, there were also workers who had worked underground and drilled for nearly 15 to 20 years without developing any symptoms.

The intoxication seemed to affect workers of all age groups. In Mine No. 1 the age at onset, of the youngest worker to be affected, was 17 years (No. 2) and the oldest 35 years (No. 9). In Mine No. 9 the youngest was 25 years (No. 879) and the oldest 44 years (No. 881). The personal habits of the patient, like intake of alcohol or tobacco, bhang or ganja or the previous history of a syphilitic infection were not predisposing or precipitating factors for the onset of this condition.

TABLE VII

Symptoms of Chronic Manganese Poisoning (Mine No. 1)

Registered No.: Name:	Patients															
	No.1 R.H.	No.2 O.M.	No.3 C.G.	No.4 N.G.	No.5 T.R.	No.6 A.K.	No.9 J.S.	No.10 R.M.	No.11 R.K.	No.13 G.I.	No.14 R.T.	No.15 T.J.	No.16 S.G.	No.18 K.N.	No.19 J.K.	Total 15
Period of Dust Exposure:	2 yrs.	2½ yrs.	6 yrs.	3 yrs.	4 yrs.	2 yrs.	1½ yrs.	2–3 yrs.	1 yr.	6 mths.	1 yr.	2 yrs.	1 yr.	6 mths.	1½ yrs.	
Difficulty in Walking	+	+	±	+	+	+	±	±	±	±	±	—	+	+	—	15
Asthenia	±	+	± +	+	+	+	±	—	±	+	—	±	+	±	+	14
Clumsiness in Movements	±	±	+	±	±	+	—	—	±	±	—	±	±	±	+	13
Speech Affected	+	±	+ +	± +	+	+ +	+	+	± +	±	+	—	—	—	—	12
Muscle Cramps	±	+	±	+ +	±	±	—	—	±	—	±	—	±	—	±	10
Anorexia	+	+	+	+	+	±	—	—	±	—	±	±	—	—	—	9
Lack of Concentration	+	+	±	±	—	—	—	—	±	—	±	—	—	—	±	8
Impotence	+	+	—	—	—	+	—	—	+	—	+	—	—	—	±	7
Somnolence	—	—	+	±	—	—	+	+	—	±	+	—	—	±	+	7
Weeping	±	±	—	±	—	—	+	—	+	—	±	—	—	—	—	6
Insomnia	—	+	±	—	+	—	—	—	—	—	—	±	±	—	—	6
Mental Irritability	—	+	±	—	± ±	—	—	—	—	—	—	—	—	—	—	4
Tremors	—	—	—	—	—	—	—	—	—	+	±	±	—	—	±	4
Intellect Impaired	±	±	—	—	+	—	—	—	±	—	—	—	—	—	—	4
Abnormal Behaviour	—	+	—	—	+	—	—	—	+	—	—	—	—	—	—	3
Memory Impaired	±	±	—	±	—	—	—	—	—	—	—	—	—	—	—	3
Lumbar Pain	—	—	—	—	—	—	—	—	—	—	—	—	—	—	±	1
Temporary Insanity	—	—	—	—	—	—	—	—	+	—	—	—	—	—	—	1
Tingling	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
Cough	—	—	+	—	±	—	—	—	—	—	±	—	—	—	—	4
Breathlessness	—	—	—	—	±	—	—	—	+	—	—	—	—	—	—	2
Haemoptysis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0

+ ÷ Markedly affected. ÷ Present or good. — Absent or impaired.

TABLE VIII

Symptoms of Chronic Manganese Poisoning (Mine No. 9)

Registered No.: Name:	Patients												
	797 G.H.	820 M.T.	821 B.D.	825 N.B.	845 A.H.	870 M.C.	878 T.B.	879 A.M.	880 Y.P.	881 F.M.	883 M.T.	884 C.G.	889 S.M.	Total 13
Period of dust epxosure:	14 yrs.	4 yrs.	7 mths.	2 yrs.	4 yrs.	11 yrs.	2 yrs.	9–12 mths.	4 yrs.	8 yrs.	17 yrs.	1 yr.	11 yrs.	
Asthenia	+	+	+	+	+	+	+	+	+	+	+	+	+	13
Difficulty in walking	+	+	+	+	+	+	+	+	+	+	+	+	+	13
Tingling	+	—	—	—	+	—	+	—	+	—	+	+	+	10
Clumsiness in movements	+	+	+	+	+	—	—	—	—	+	—	+	—	9
Lumbar Pain	—	+	+	+	+	—	—	—	+	—	+	+	+	9
Excessive Laughter	+	+	—	+	+	—	+	—	—	+	+	+	+	8
Mental Irritability	+	+	—	—	+	—	—	+	—	+	+	+	+	8
Speech Affected	+	+	—	+	—	—	+	+	+	+	—	—	—	7
Cough	+	+	+	+	+	—	—	—	—	+	—	—	+	7
Anorexia	+	+	+	—	+	—	—	—	—	—	—	+	—	6
Muscle Cramps	+	—	—	—	+	—	+	—	+	—	—	+	+	6
Weeping	—	—	—	—	+	—	—	+	+	+	+	—	—	6
Temporary Insanity	+	+	—	—	+	+	—	+	—	—	—	—	—	6
Somnolence	+	—	—	—	—	—	—	+	—	+	+	+	—	5
Trimors	+	+	—	—	—	—	—	—	+	—	—	—	—	4
Insomnia	+	+	—	—	—	—	—	—	—	—	—	—	—	4
Abnormal behaviour	—	+	—	—	+	+	—	—	—	—	—	—	—	3
Lack of Concentration	—	+	—	—	—	—	—	+	—	—	—	—	—	2
Breathlessness	+	—	—	—	—	—	—	—	—	—	—	—	+	2
Haemoptysis	+	—	—	—	—	—	—	—	—	—	—	—	+	2
Intellect Affected	—	—	—	—	—	—	—	—	—	—	—	—	—	0
Memory Impaired	—	—	—	—	—	—	—	—	—	—	—	—	—	0

+ Present or good. — Absent or impaired.

Symptoms

The earliest complaint made by the affected persons was that of asthenia and a tendency to get easily tired even by a small effort. 27 out of 28 patients complained of this. Previously healthy and active and doing a full day's work, the patient found that he was getting slower; lifting the drill or boring a hole became too much of an effort. He had to do it with many pauses. In between drilling fresh holes he needed longer periods of rest. His daily output of ore production started dropping. At the end of the day he found himself dead beat and could take no part in any recreation or sports like many of his colleagues.

Accompanying or immediately following asthenia as a symptom was anorexia. It was complained of by 15 patients. The desire to eat and the food intake dropped considerably with the onset of the intoxication. At times there was an associated fall in body weight. It was however noticed that either having left the work completely or being transferred to the surface to do some other odd job, the patient's appetite improved, he put on weight and the asthenia disappeared. In fact, this improvement was noticed with a general arrest in the downward progress of the disease. The patients who were brought to Bombay for special investigation had been away from their work for 2 to 4 years and they showed excellent general health and had a very healthy appetite.

Difficulty in walking, altered gait and increasing tendency to falls were the most striking and consistent neurological complaints—in fact, all patients complained of it. The patient noticed that walking became more jerkey, the balance was imperfect and there was a tendency to run especially if he was going down even a slight slope. Going up and down the mine incline became difficult and there were frequent falls and bruises. Coming up the mine steps definitely became slower. Turning around suddenly and squatting became impossible and led to falls. There was a tendency to lose the balance specially with a heavy object like a drill in the hands. Abnormal gait was not as early a symptom as the above two, but it often followed rapidly in their wake and was more obvious. The difficulty in walking increased considerably with time but none of the workers were completely taken off their feet or were bed-ridden.

Painful muscle cramps involving the lower limbs specially the calf muscles, which were worse at night, were noticed by 16 patients and low lumbar pain and backache by 10 patients. Backache appeared to be far commoner in Mine No. 9 than in

Mine No. 1. Pain in the chest, of a muscular nature was experienced by many workers.

Mental irritability, lack of concentration and uncontrolled temper were not uncommon. The patient often expressed a desire to be left along and preferred his own company to that of his erstwhile companions. Three of them complained of a failing memory and dulled intellect, although our objective testing revealed no evidence of it. Again, as previously noted in the other symptoms, in the arrested cases who had left the mines, the above symptoms were not evident. In fact, there was a tendency for these patients to remain as a group, with a lot of fellow-feeling amongst them.

One patient from Mine No. 1 and six patients from Mine No. 9 gave a history of temporary insanity, some time before the onset of the other neurological symptoms. The onset of these episodes was sudden—in most cases starting with acts of violence, or a big outburst of temper or an unnecessary quarrel. The patient would wander about aimlessly and talk irrelevantly; considerable confusion of thought and disorientation was noted by friends and relatives. At times the whole condition lasted for 15 to 20 days and subsided completely, whilst in two of them it lasted for six months to a year and they had to be confined to a mental asylum. All except one patient regained their sanity completely. The one who was not normal mentally, had not resumed work and was prone to excessive emotional outbursts. He cried on the least provocation and talked of nothing else but his own condition. Previously a good worker, he had become a burden to his family. These episodes of temporary insanity, we believe, may be some form of manganese intoxication, especially as in all these cases other manifestations of manganism followed. There were a few other workers who gave similar history of temporary insanity but as they had no other evidence of intoxication, we have excluded them from the analysis as it is impossible to say whether this was due to manganese or some other form of psychosis.

Excessive laughter was complained of by 13 patients from Mine No. 1 and 8 from Mine No. 9. In three of them it was mild, and only noticed by the relatives who knew the patient's previous background and thought the sudden smiles and laughter to be unusual by contrast to the patient's usual demeanour. In two of them it was a passing phase lasting for a year or so at the beginning of the complaint. In others, it became an increasingly noticeable complaint. The laughter was often at inappropriate moments and often without any adequate provocation.

Spontaneous and unprovoked weeping was noticed by the relatives of 12 patients. This disturbance of mood was not so marked or so persistent as of excessive laughter, but was remarkable to the relatives as the patients, who were tough miners, previous to their affliction were not easily moved to tears.

Disturbance of speech and voice was noticed relatively late by most patients and came often after several months of the onset of the condition. The speech became gradually indistinct and hard to understand, and the voice became softer and hardly audible. Except his most intimate friends and relatives no one could understand most of what the patient said, specially in the more severe cases. 19, out of the total of 28 patients gave a history of defective speech and voice. Excessive salivation was complained of by nearly a third of the affected patients.

Diminished libido or impotence was complained of in ten cases. It was difficult to decide whether this was the earliest manifestation or not, but when present, it was fairly early in the development of the symptomatology.

Disturbance of sleep rhythm, either insomnia or somnolence was often noticed. It was never a very disturbing phenomenon. Whilst insomnia was evanescent and lasted for a few months only, somnolence seemed to get more marked with increasing disability.

Along with clumsiness in gait and poor balance in walking, quite a few of the patients found that it was difficult to handle objects like coins, buttons, etc., and it took longer to dress, wash and do similar acts. They felt that their physical activity had slowed. Quite a few of them complained of tremors in the hands specially whilst lifting objects, but on objective examination we could not confirm it in more than six of them.

Sensory symptoms were hardly mentioned. Ten persons from Mine No. 9 noted that they had occasional tingling in the fingers, specially at the tips. None from Mine No. 1 complained of this symptom.

TABLE IX

Signs of Chronic Manganese Poisoning (Mine No. 1)

	Patients															
Registered No. Name:	No. 1 R.H.	No. 2 O.M.	No. 3 C.G.	No. 4 N.G.	No. 5 T.R.	No. 6 A.K.	No. 9 J.S.	No. 10 R.M.	No. 11 R.K.	No. 13 G.I.	No. 14 R.T.	No. 15 T.J.	No. 16 S.G.	No. 18 K.N.	No. 19 J.K.	Total 15
Period of Dust Exposure:	2 Yrs.	2½ Yrs.	6 Yrs.	3 Yrs.	4 Yrs.	2 Yrs.	1½ Yrs.	2–3 Yrs.	1 Yr.	6 mths.	1 Yr.	2 Yrs.	1 Yr.	6 mths	1½ Yrs.	
Depression	—	—	—	—	+	—	+÷	—	+	—	÷	—	—	—	—	4
Laughter	++	++	÷	+÷	+	+÷	—	++	÷	+	—	÷+	+	—	+	12
Weeping	—	+	—	—	—	—	—	—	—	—	÷	—	—	—	—	2
Expressionless Face	++	+	÷	++	÷	+	+	—	+÷	÷	+	÷	÷	—	÷	13
Salivation	÷	+	—	+	—	—	+	—	÷	—	—	+	—	—	—	6
Abnormal gait	++	+	+	++	+	++	÷	+	++	+	+	÷	+	—	—	13
Cock walk	—	+	+	÷÷	—	÷+	—	—	—	—	—	+	—	—	—	5
Retropulsion	++	÷	+÷	+	++	++	—	+	++	++	++	—	—	++	—	11
Propulsion	÷	+	++	+	—	+	—	÷	÷	+	÷	+	—	—	—	10
Beam sign	+	÷	÷	+	÷	÷	—	+	÷	÷	÷	+	—	—	—	11
I.Q.	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	NN
Speech defect	+	+	+	÷÷	÷	÷+	++	+	+	++	÷	÷	+	—	—	13
Low voice	÷	++	÷÷	++	+	++	÷÷	+	÷÷	÷÷	÷	÷	—	—	÷	13
Diminished power UL	÷	+	+	+	÷	÷	+	÷	+	÷	+	+	+	÷	+	15
LL	+	+	+	÷	÷	+	+	÷	+	+	÷	—	+	+	÷	15
Increased tone UL	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
LL	÷	—	+	÷	—	÷	—	—	—	—	—	—	—	—	—	4
Impaired (slow) Coodination & Fine movements UL	+	÷	++	÷	+	÷	÷	—	—	+	—	+	÷	—	—	10
LL	÷	+	++	+	+	+	+	—	—	+	—	+	+	—	—	10

TABLE IX—*contd.*

Signs of Chronic Manganese Poisoning (Mine No. 1)

	Patients																
Registered No. / Name:	No. 1 R.H.	No. 2 O.M.	No. 3 C.G.	No. 4 N.G.	No. 5 T.R.	No. 6 A.K.	No. 9 J.S.	No. 10 R.M.	No. 11 R.K.	No. 13 G.I.	No. 14 R.T.	No. 15 T.J.	No. 16 S.G.	No. 18 K.N.	No. 19 J.K.	Total 15
Period of Dust Exposure:	2 Yrs.	2½ Yrs.	6 Yrs.	3 Yrs.	4 Yrs.	2 Yrs.	1½ Yrs.	2–3 Yrs.	1 Yr.	6 mths.	1 Yr.	2 Yrs.	1 Yr.	6 mths.	1½ Yrs.	
Tremors UL	—	—	÷(Tongue)	—	—	—	—	—	—	÷÷Course	+Fine	+Fine	—	—	—	4
LL	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0
Deep reflexes UL	÷	+	+	+	+	+(÷)+		+	+	+	+	+(÷)	+	+	+	2B 13+
LL	÷+	+	+(÷)	+(÷)	+	+(+)	+(+)		+	+(÷)	+	++	+	÷	+(÷)	2E 6B 7+
Plantars RT															2EX 1EQ 12F	
LT															2EX 1EQ 12F	
Micrographia	Illiterate	—	÷	Illiterate	—	+	÷	Illiterate	÷	+	—	÷	—	—	—	6
Granding	Severe	Severe	Severe	Severe	Moderate	Severe	Moderate	Mild	Severe	Moderate	Moderate	Severe	Mild	Mild	Mild	4 mild 4 moderate 7 severe

F=Flexor; E=Exaggerated; B=Brisk; EQ=Equivocal; Ex=Extensor; +Present or good; —Absent or impaired.

TABLE X

Signs of Chronic Manganese Poisoning (Mine No.9)

		Patients													
Registred No.		797	820	821	825	845	870	878	879	880	881	883	884	889	Total
Name:		G.H.	M.T.	B.D.	N.B.	A.H.	M.C.	T.B.	A.M.	V.P.	F.M.	M.T.	C.G.	M.S.	13
Period of Dust Exposure		14 yrs.	4 yrs.	7 mths.	2 yrs.	4 yrs.	11 yrs.	2 yrs.	9–12 mths.	4 yrs.	8 yrs.	17 yrs.	1 yrs.	11 yrs.	
Depression		—	±	—	—	—	—	+	+	+	—	—	—	+	5
Laughter		±	—	—	—	—	—	—	—	—	—	—	—	—	1
Weeping		—	—	—	—	—	—	—	+	—	—	—	—	—	1
Expressionless face		±	+	±	+	—	—	±	—	+	±	—	+	—	8
Salivation		—	—	—	—	—	—	—	—	—	+	—	—	—	1
Abnormal gait		+	±	+	+	+	—	+	—	+	+	±	±	+	11
Cock walk		—	—	—	—	—	—	—	—	—	—	—	—	—	0
Retropulsion		+	±	+	—	—	—	++	—	—	++	++	++	+	8
Beam sign		—	—	—	—	—	—	+	—	—	+	+	+	—	4
I.Q.		N	N	N	N	N	N	N	N	N	N	N	N	N	0
Speech defect		+	±	—	±	—	—	±	—	—	±	—	±	—	6
Low voice		±	±	—	±	—	—	±	—	—	+	—	+	—	6
Diminished power	UL	±	—	—	—	+	—	—	—	—	+	—	+	—	4
	LL	+	—	—	—	+	—	—	—	+	±	—	+	—	5
Increased tone	UL	—	—	—	—	—	—	—	—	—	±	—	±	—	2
	LL	+Ankle clonus	+Ankle clonus		—+Ankle clonus		+Ankle clonus	—	—	+	+	+	+	—	8
Impaired (slow) Coordination and fine movements	UL	±	+	—	—	+	—	—	—	+	±	—	±	—	6

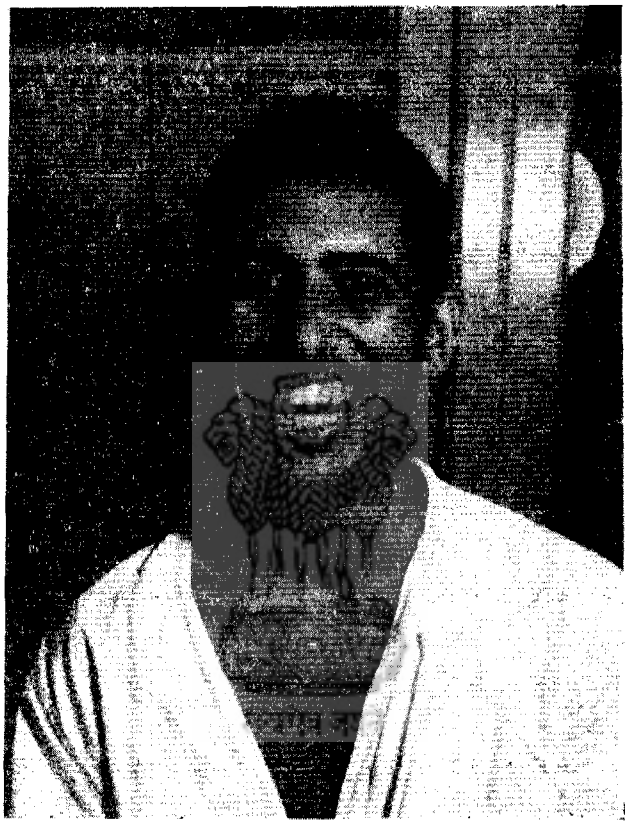
TABLE X—*contd.*

Signs of Chronic Manganese Poisoning (Mine No. 1)

		Patients													
Registred No.		797	820	821	825	845	870	878	879	880	881	183	884	889	Total
Name:		G.H.	M.T.	B.D.	N.B.	A.H.	M.C.	T.B.	A.M.	Y.P.	F.M.	M.T.	C.G.	M.S.	13
Period of Dust Exposure		14 yrs.	4 yrs.	7 mths.	2 yrs.	4 yrs.	11 yrs.	2 mths-	9-12 yrs.	4 yrs.	8 yrs.	17 yrs.	1 yrs.	11 yrs.	
Tremors	LL	+	—	—	—	+	—	—	—	+	+	—	+	—	6
	UL	—	Fine	—	—	—	—	Coarse	—	—	—	—	—	—	2
	LL	—	—	—	—	—	—	—	—	—	—	—	—	—	0
Deep reflexes	UL	+(+)	+(+)	+	+	+	+	+	+	++	+	+	+(+)	+(+)	3E4B6 –
	LL	++	+(+)	+	+	+	+	+	+	++	+	+	+(+)	+	5E2B6 –
Plantars	RT														4EQ1EX8F
	LT														
Micrographia		Illiterate	—	—	—	—	—	—	—	—	—	—	—	—	0
Grading		Mild	Mild	Mild	Mild	Mild	Mild	Severe	Mild	Mild	Severe	Moderate	Severe	Mild	9 Mild 1 Moderate 3 Severe

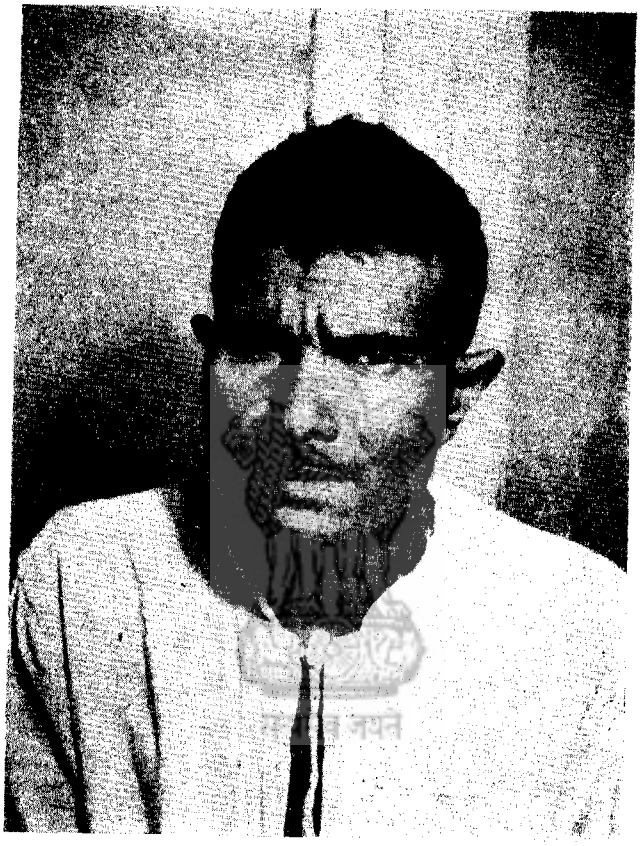
F=Flexor E=Exaggerated; B=Brisk; EQ=Equivocal EX=Extensor; +Present or good; — Absent or impaired.

Fig. VIII.



Laughing Mask

Fig. IX.



Sad Mask.

The striking features of the examination were a fixed mask-like face, pathological laughter, low indistinct speech, abnormal gait and retropulsion, slightly diminished power in the limbs with slowness of all movements of the body and micrographia.

At rest and when not laughing, the face was unwrinkled and emotionless, there was very little blinking of the eyes and it could be best compared to a mask, and like a mask, in some it was a 'happy' one and in others a 'sad' one. (Figures VIII and IX). The Parkinsonian face was found in all severe and several mild cases suggesting that it was an early feature in the development of this condition. Thirteen out of the fifteen cases at Mine No. 1 and eight out of thirteen cases at Mine No. 9 showed such features. In some of them, there was collection of excessive saliva in the mouth and at most times they were clearing their throats or giving little coughs to prevent saliva from trickling down the trachea. Occasionally there was dribbling of saliva as seen in other similar condition such as post-Encephilitic Parkinsonism. The dribbling was much more evident during outbursts of laughter. There was no excessive sweating or seborrhoea on the face.

Quite a few of the established cases showed euphoria. Abnormal or pathological laughter was extremely striking, but interestingly enough was seen in many more patients at Mine No. 1 than Mine No. 9. It is possible that this was so because there were many more severely affected cases at the former mine; but even the severe cases at Mine No. 9 did not show this tendency. Unlike the immobile faces, it was not an early manifestation and was not seen in mild cases. Twelve out of fifteen patients at Mine No. 1 and only one patient at Mine No. 9 exhibited this laughter when we examined them. The case at Mine No. 9 was a mild case, and there was no true laughter as compared to the Mine No. 1 cases, but he showed a tendency to excessive smiling and grinning at the least provocation. The laughter when present was typical. It was spontaneous at times, but often evoked by a simple question or a friendly smile or even a look of recognition on the part of the examiner. Once started, the smile broke into a grin and the grin into a rapidly growing voluminous laughter. At times there would be a high pitched crowing noise as a termination to the rising laughter. Such spells would be frequent and throughout the day, specially when several such patients were kept together in one ward; a smile to one of them would spark off a round of laughter passing back and forth from one to the other. At times there was some semblance of amusement with the laughter, but at most times the physical expression of laughter was out of all proportion to its emotional

Fig. X.

Taking time to get off the mark.

content. In fact, no satisfactory explanation was forthcoming from the patients when questioned about the cause of the laughter. Most of them stated that they were actually unhappy about, and were embarrassed by the laughter which was beyond their control.

Weeping and depression were less common. A history of this complaint has been mentioned before but we saw only three patients actually weep in our presence and none of them gave adequate reason for it but mentioned that it was beyond their control and thoroughly embarrassing. Nine patients, inclusive of the above three showed very unhappy, depressed, masklike faces, and could not be stimulated to even a small smile.

The speech specially in advanced cases was slurred, very inarticulate and incomprehensible. The patient hardly opened his mouth whilst speaking. The voice was very low and there was no force behind it. The speech was completely rhythmless and monotonous. There was also a striking inability on the part of these patients to raise the voice or shout aloud.

The gait was abnormal in twenty-four of the twenty-eight patients. It varied in severity from patient to patient. It was a mixture of several parts. At its worst, the patient almost ran instead of walking. He would take a little time to get off the mark (Figure X) and then leaning forward, go into a rapidly faster walk at times terminating with a fall (propulsion). The balance was poor, he often rolled from side to side and did not always go along a straight line. Most of the patients walked with a wide base, with a few showing a tendency to "scissoring". Five of them showed what has been described by others as a "cock walk", *i.e.* walking on the ball of the foot and toes only, with heels well off the ground. Whilst propulsion was often present, retropulsion was a more marked feature of this disease. Going backwards was very difficult. The patient would start slowly and then the steps would increase with uncontrolled speed, ultimately resulting in a fall. At times more than one step backwards was impossible, any further effort ending with a heavy fall. Trying to squat was impossible, it always resulted in a backward tumble. Going up a ladder was dangerous and cycling became difficult. When the patient stood erect with his feet together, a gentle push pitched him backward as if in one column. The whole body behaved like a rigid log or beam standing on one end and on the least push fell in the direction of the push; however, in one patient it was possible to push him only backwards.

The first impression created on the examiner on meeting most of these patients was that they were mentally subnormal. The masklike face, the continual grin or laughter and the dribbling

saliva gave the impression that they were idiots but subsequent conversation and examination completely changed that impression. The intelligence, memory and behaviour during our examinations appeared normal. Some of them showed poor concentration and attention. Formal Intelligence Quotient tests were carried out in nine such patients and it was reported that the scoring was normal or above normal, of course, considering the intellectual background of education and circumstances of the patients.

The motor system revealed a few abnormalities. All the patients at Mine No. 1 and five patients at Mine No. 9 had a very mild weakness of all the four limbs. Their grip was poor and for hard manual labourers the power seemed insufficient to overcome the forceful resistance from the not too strong examiners. It did not appear like true paralysis but merely a slowness in initiation of movement and a lack of sufficient effort on the part of the patients. There was no wasting of muscles and it was difficult to decide whether this 'weakness' was due to true pyramidal damage or a mere slowness of extrapyramidal origin, specially in view of the fact that in seven of them there was other evidence, albeit mild, of pyramidal damage, although restricted only to the lower limbs.

There was no increase in tone in the upper limbs in a single patient at Mine No. 1 and a mild increase in two patients from Mine No. 9 (unlike other varieties of Parkinson's disease). Twelve patients in all showed a slight increase in tone in the lower limbs, more in the extensor than in the flexor group. The ankle clonus was present in four of them. In contrast to the obvious increase in tone on walking which was exhibited by the "cock walk", the absence of markedly increased tone in the lower limbs whilst lying in bed became more striking. The increased tone on standing was also shown by the fact that when pushed, the patient fell backward like a solid log.

All body movements, specially the finer movements and the alternating movements were slowly performed, but there was no true incoordination or ataxia—the finger-nose and heel-knee tests were normal.

Tremor as seen in other varieties of Parkinson's disease was not seen in a single case. However, three patients showed a fine tremor and two a coarse tremor of the outstretched hands and fingers. One patient showed a coarse tremor of the tongue.

The upper limb reflexes were exaggerated in only three patients. The lower limb reflexes were brisk in eight cases and exaggerated in seven. The abdominal reflexes were always present

and the plantar responses were extensor in three and equivocal in five patients. In fact, we were able to accept only seven patients as showing signs of mild pyramidal damage, which was almost entirely in the lower limbs. Those who had brisk reflexes, or equivocal plantar responses or increased tone, by itself, were not accepted as cases showing pyramidal signs.

Typical micrographia (Figure XI) was noticed in six patients only. But a large number of workers examined by us were illiterate and could not write. In some of them an attempt was made to test for this sign by asking them to draw circles in a row. However, this method proved to be unsatisfactory for lack of cooperation and many patients rightly pointed out that as they had never held a pencil in their hands before, the performance would naturally be vitiated. Fig. XI :

The skull, spine, fundi, cranial nerves and sensations were completely normal. In three or four patients there was some sensory blunting to pin-prick up to inguinal ligaments. This was so inconsistent on repeated examination that it was thought to be due to an inability on the part of the patients to understand the test than a true sensory loss.

Progress :

The progress of the disease was gradual, and some of the patients mildly afflicted had noticed their first symptoms some five years ago and were still working in the mines. The progres was thus very slow and hardly noticeable. On the other hand, most of the severe cases developed within a matter of six to nine months; as the progressively deteriorating symptoms rapidly followed each other, all the severe cases were unfit to carry on work and were taken out of the underground jobs, specially drilling or completely put off work, on reporting the first symptoms. Some of the workers at Mine No. 1 who were aware of the hazards of their occupation actually reported sick and went off work within a month of the onset of the weakness of the legs or on noticing difficulty in walking. It is possible in most cases that the other symptoms of asthenia, anorexia, irritability, etc. were the early heralds of the intoxication but the patients may not have paid any attention to this warning of more severe illness to follow. However, even if they left their work within weeks of the onset of difficulty in walking, the disease

progressed, and for nearly three to six months the disability increased and then further deterioration ceased. We saw none of the workers bed-ridden due to progressive disability. Some of the affected persons have been under the observation of one of us for nearly five years and the disease once established has not got worse. In some there has been slight though appreciable improvement. In one or two, the speech was a little more distinct or the pathological laughter a little less evident or the gait more controlled, but no remarkable cures have been reported once the disease has been established, even in a mild form. The tendency is to maintain a *status quo,* after a certain initial deterioration, provided the patients are removed from further dust contact. A longer follow up of the cases is obviously necessary.

The detailed case histories of the 28 positive cases are given in Appendix I.

(2) *Doubtful Cases*

As mentioned earlier, there were nine patients whose condition could not be specifically grouped, as due to the deleterious effect of manganese. All these patients were working in Mine No. 1.

There were seven patients who had various complaints of anorexia, asthenia, muscle cramps, irritability, easy fatiguability, depression, impotence, lack of concentration in their work and a failing memory. On examination none of them showed any abnormal physical signs. Some of them had rather brisk deep reflexes but no evidence of neurological disease. One of them has been under observation for nearly 2 years (Case 20), and he has continued to work as an underground driller. Although he continues to have the symptoms, no obvious signs of nervous disease have as yet become evident. Taking this case just as an example, how is one to determine which of these are cases of pre-manganism, from the direct effects of the dust and which are merely neurotics, hysterics or malingerers who know of the hazards of their work? Two of the other patients had a past history of short episodes of mental derangement lasting for a few months. One of them had no symptoms or signs at the time of examination. One had symptoms of anorexia, asthenia, irritability, etc., although he had mentally recovered, and had no physical signs. As temporary insanity has been described by other workers as a precursor of full-blown manganism, are we justified in labelling these patients as suffering from premanganism or are these mere psychotic episodes unconnected with the dust exposure in their work? We shall discuss this further later.

(3) *A group of neurological cases with similar manifestations but other than those of classical manganism*

We detected seven such cases. One case was from Mine No. 1, two from Mine No. 9 and four from Mine No. 10 (where no classical manganese intoxication cases were detected). In all these patients the main complaint was a progressive difficulty in walking, climbing up and coming down the slopes. The condition had been gradually progressive over four to seven years. No sensory, emotional or psychic disturbances were noted. The upper limbs were reported to be normal.

In all of them it was noticed that the physical signs were entirely restricted to the lower limbs. There was a mild to moderate symmetrical weakness with markedly increased tone, leading to a spastic or "scissors" gait. The lower limb reflexes were exaggerated and an ankle clonus obtained in all cases. The plantar response was extensor in two, but equivocal in four and flexor in one. The abdominal reflexes were present in some and absent in the others. No sensory signs were elicited. The faces were normal and no pathological laughter was noticed. In fact, the condition was one of spastic paraplegia, which could best be classed as Primary Lateral Sclerosis. All these patients work in an area where Lathyrism (a variety of Primary Lateral Sclerosis) prevails. Three of them denied having taken Kesari (Lakhori or Tewra) dal, which is supposed to cause this complaint. The other four had been consuming Lakhori dal 'fairly regularly' for some years before the onset of the complaint. It is quite possible that these patients were suffering from Lathyrism (in spite of the not very adequate history of intake of the appropriate "dal" in all cases) specially as this condition is quite common in these parts of India. The relationship betwen lathyrism and manganese intoxication is discussed later.

Detailed histories of these seven cases are given in Appendix II.

Fig. XII.

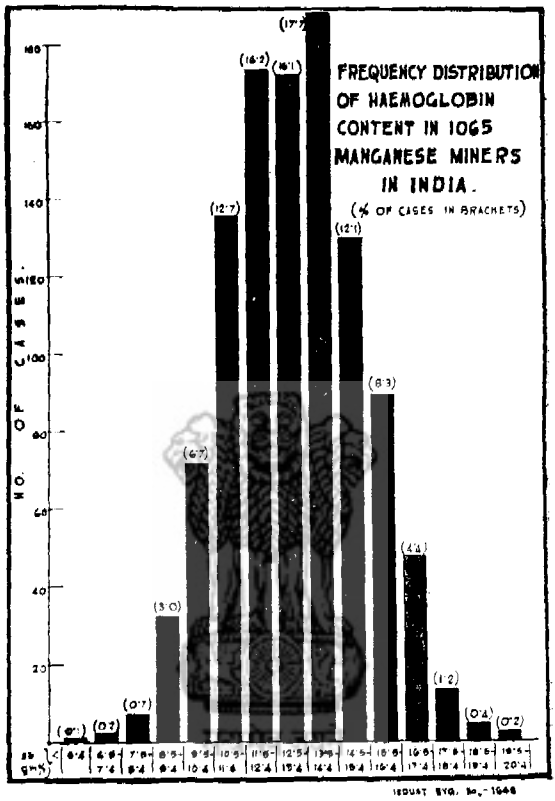
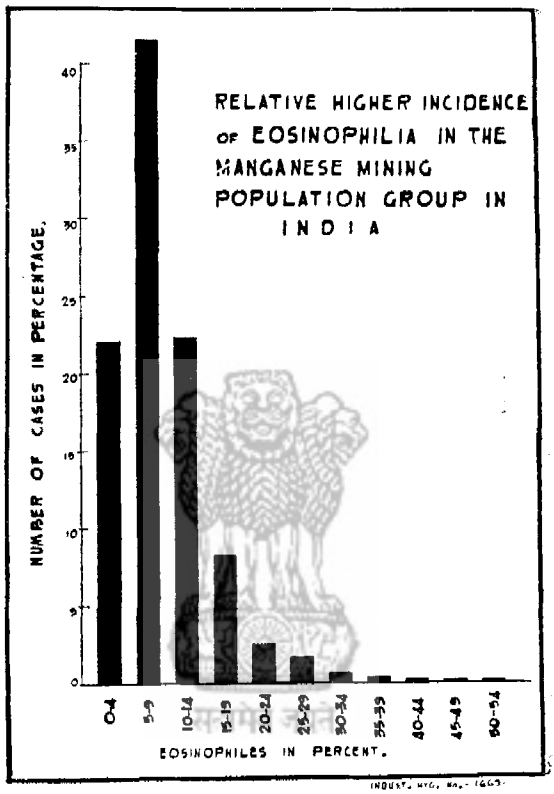

FREQUENCY DISTRIBUTION
OF HAEMOGLOBIN
CONTENT IN 1065
MANGANESE MINERS
IN INDIA.
(% OF CASES IN BRACKETS)
NO. OF CASES.
(17·7)
(16·2)
(16·1)
(12·7)
(12·1)
(8·3)
(6·7)
(4·1)
(3·0)
(1·2)
(0·4)
(0·7)
(0·2)
(0·1)
160
140
120
100
80
60
40
20
Hb gm%
< 6·4
6·5 - 7·4
7·5 - 8·4
8·5 - 9·4
9·5 - 10·4
10·5 - 11·4
11·5 - 12·4
12·5 - 13·4
13·5 - 14·4
14·5 - 15·4
15·5 - 16·4
16·5 - 17·4
17·5 - 18·4
18·5 - 19·4
19·5 - 20·4

Fig. XIII.


RELATIVE HIGHER INCIDENCE
OF EOSINOPHILIA IN THE
MANGANESE MINING
POPULATION GROUP IN
INDIA
NUMBER OF CASES IN PERCENTAGE.
40
35
30
25
20
15
10
5
0
0-4
5-9
10-14
15-19
20-24
25-29
30-34
35-39
40-44
45-49
50-54
EOSINOPHILES IN PERCENT.

CHAPTER V

MANGANESE INTOXICATION—SPECIAL INVESTIGATION

The investigations carried out were (1) field investigations at the mines and near about hospitals and (2) hospital investigations at Bombay. In the first category, blood Hb and differential counts were done for all patients, and for a few, full blood counts were also done; chest X-Rays of nearly 25% of the workers seen by us were also taken. At the J. J. Hospital, Bombay, detailed investigations of nine positive cases of manganism were made.

(1) *Field Investigations*

(*a*) Blood Studies :

It was decided at the outset to examine the blood of all workers who were selected for clinical examination, regardless of whether they were suffering from any disease or not. It was, however, possible to carry out only the Hb% and the white blood cell differential count in all the workers examined. The total red cell and white cell counts were done in the first mine on a few workers and later, because the total counts were coming near normal and because of the impossibility of doing a large number of counts in a day by one or two persons, with any degree of consistent accuracy, the total counting of cells was dropped.

The Haemoglobin percentage estimation (Hellige) was revealing in that the Hb% was on the high side of normal or higher than normal in a large number of workers specially considering that poor diet and ankylostomiasis would tend to cause anaemia. The average Hb for the total number examined was 12.54% (amongst 973 workers—see Figure XII). In the underground mine No. 1, the average Hb% was higher (12.69 gms.% $\pm$ 2.72) that in the open cast mines in the district around. In the open cast mines, Nos. 2, 3, 4 & 5 respectively, it was 11.83 gms.%, 10.95 gms.%, 10.68 gms.% and 11.50 gms.%. Considering that the nutritional status of the patients in Mine No. 1 was the poorest, the high Hb% figure is revealing. At the underground mine No. 9 it was 14.02 ($\pm$1.50) gms.% and in neighbouring open cast mine No. 10 it was significantly lower—12.51 gms.% ($\pm$1.40—P—less than 1%).

TABLE XI

Statistical constants of Comparison of Haemotological Examination in 63 Manganese Miners of Mine No. 1 and 56 Villagers (Control Group) showing a high Haemoglobin & Total Counts amongst the former.

	HAEMOGLOBIN			TOTAL COUNTS					
	In grams %			Total RBC			Total WBC		
	M	SD	t	M	SD	t	M	SD	t
Underground miners ..	16·08	±2·56	2·10 (S:5%)	5·05	±0·85	4·1538 (S: 1%)	10,223	±2902·65	1·9848 (S: 5%)
Control population ..	15·24	±1·69		4·51	±0·57		9,272	±2272·88	

	DIFFERENTIAL COUNTS											
	Polymorpho-nucleus			Lymphocytes			Eosinophilia			Monocytes		
	M	SD	t	M	SD	t	M	SD	m	M	SD	t
Underground miners	65·75	±8·71	0·3803 (NS)	23·83	±4·34	0·3095 (NS)	9·27	±10·17	0·0795 (NS)	1·71	±1·20	0·3636 (NS)
Control population ..	65·21	±6·59		23·57	±4·67		9·41	±8·91		1·79	±1·16	

M = Mean; SD = Standard Deviation; t = "Critical Ratio"; S = Significant at % level; NS = Not Significant.

Eosinophilia was the most characteristic feature of the differential count (Figure XIII). The patients who were brought to Bombay did show an eosinophilia but the R.B.C. count and Hb% were not so strikingly elevated. This is mentioned later.

To make certain that the rise in Hb% and the eosinophilia count was directly associated with the work the patients were doing, Mine No. 1 was revisited and a complete total white and red cell count, and Hb% and differential count were carried out by one person, of all the cases previously examined by us. As a control a similar number of random samples were taken from the mining village from volunteers who were not miners but lived in the village in various other capacities as dependents of miners, school teachers, shopkeepers, farmers etc.,—all adult males. This study (Table XI) revealed that the high eosinophilia was not only confined to the miners but was also noticed in the neighbouring population. The average, in this study, of eosinophilia in miners was 9.3% of the total white cells, with the highest count at 66% of the total and in the controls 9% with the highest count at 41%. The average Hb% and red blood cell count respectively of the miners was 16.08 gm% and 5.05 mill/cmm, and of the villagers was 15.24 gm.% and 4.51 mill/cmm. The rise in the R.B.C. and the higher Hb% in the miners is significant and was not restricted to any special category of workers.

(*b*) X-Ray of the Chest :

A total of 284 workers from all mines were x-rayed at different hospitals. These workers were selected after a detailed physical examination carried out in the field studies and included those suspected of having some respiratory pathology and a large number of controls.

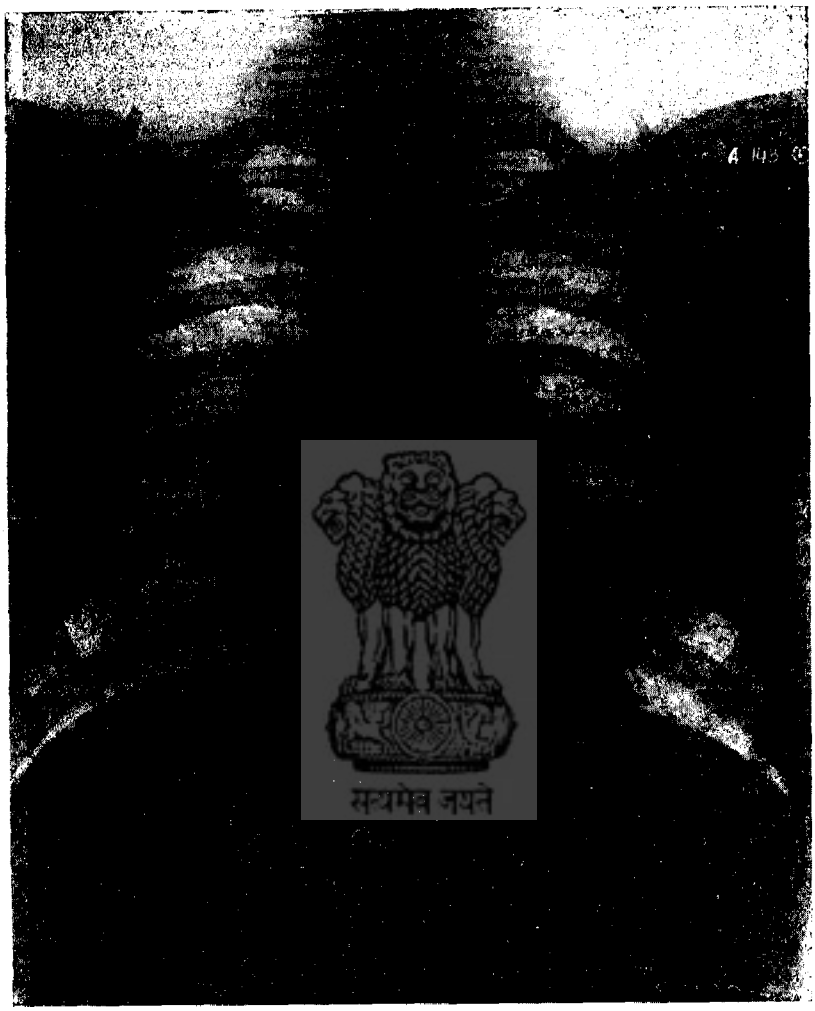
The radiological classification of the skiagrams is based on I.L.O. Classification (1959). Out of 284 skiagrams, 41 turned out to be unreadable for various technical faults found in them. The following data pertain to 243 x-ray pictures only :

TABLE XII

Classification of Chest Skiagrams

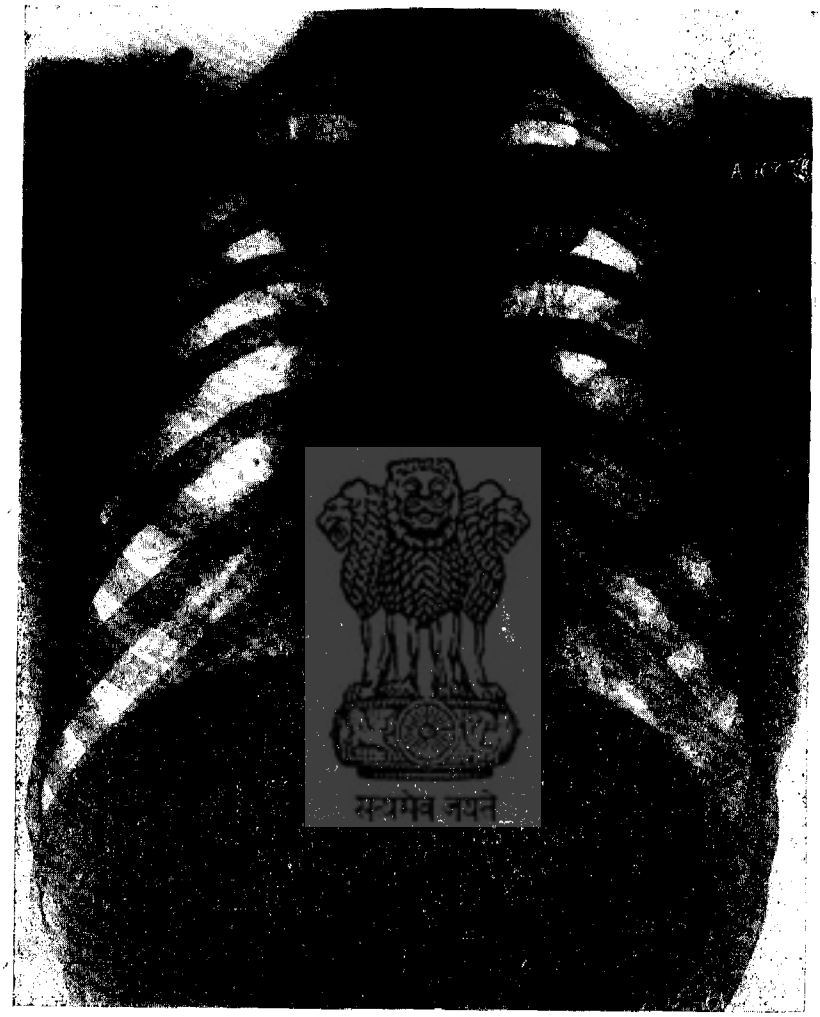
Classification	No. of cases	Percentage of cases
1. Normal	162	66·7
2. Exaggerated linear markings	46	19·0
3. Nodular simple pneumoconiosis	10	4·1
4. Tuberculosis & Pleurisy	20	8·2
5. Other respiratory pathology (emphysema, hilar enlargement).	4	6·1
6. Suspected Tropical Eosinophilia	1	0·4
TOTAL ..	243	100·0

Fig. XIV.



Case No. 576—lesion M_3 (M-Micronodular)

Fig. XV.



Case No. 653—lesion P_2 (P-Punctate)

Of the 10 cases of simple pneumoconiosis (Figures 14 & 15—case Nos. 653 and 576), six were drillers, three underground supervisors and one timberman. Eight of them were from Mine No. 7, the other two were from Mine No. 1 and 12. One of them had 1—5 years of exposure, six had 6—10 years of exposure and three had 11—15 years of exposure to manganese dust.

(2) *Detailed Investigations of the Nine Patients Brought to Bombay.*

Nine patients with undoubted diagnosis of manganism were brought to Bombay for further study. Six patients were brought from Mine No. 1 (Nos. 1, 2, 3, 4, 5, 6) and three from Mine No. 9 (797, 825, 889). The patients from Mine No. 1 were all those who had been put off work from 2 to 4 years. The patients from Mine No. 9 were brought straight from their jobs. The details of each patient's investigations are given along with their case histories in Appendix I, but the overall results are summarised here :

(*a*) *X-Rays* : A.P. and lateral views of the skull and similar views of the whole spine were done in each case and were consistently negative in all patients. The chest x-rays were also normal.

(*b*) *Sputum examination* in each case for acid fast bacilli was negative. No tests were done with the sputum to stain manganese particles or to assess its contents.

(*c*) *Routine Examination* of urine for albumen, sugar, bile salts or pigments, abnormal cells, casts, etc. was negative.

(*d*) *Liver function tests* (Table XIII). Total proteins, albumen, globulin, serum alkaline phosphatase, thymol turbidity, Icteric index, Van den Bergh reaction, all were within normal limits and showed no evidence of impaired liver function. No liver biopsy was carried out, in the absence of any clinical or laboratory evidence of liver disease.

(*e*) *Faeces* : Ova of Ankylostoma Duodenale were found in the faeces of three patients. The examinations were done repeatedly; one routine examination and one with the concentration method specially adopted to find helminthic ova, even when present in smaller numbers in the faeces.

(*f*) *Blood* : W.R. and V.D.R.L. tests were negative in all the cases.

TABLE XIII

Results of Liver Function Tests of Chronic Manganese Poisoning Cases

Case No.	Total Proteins in gms. %	Albumen in gms. %	Globulin in gms. %	Alkaline Phosphotase in K.A. Units	Thymol Turbidity in serum in units	Icteric Index in units	Van den Bergh's Reaction
1	7·1	4·4	2·7	8·7	2	5	Negative
2	7·4	4·1	3·3	8·4	1	3	Negative
3	5·8	2·8	3·0	6·6	2	5	Negative
4	7·7	4·7	3·0	5·8	1	1	Negative
5	6·9	4·0	2·9	6·4	2	3	Negative
6	7·3	4·2	3·1	5·8	3	1	Negative
797	6·5	3·7	2·8	12·1	1	7	Negative
825	7·0	4·2	2·8	10·2	3	5	Negative
889	6·3	3·7	2·6	9·4	2	3	Negative

(*g*) *The cerebrospinal fluid* routine examination was done in every case (Table XIV). It consisted of pressure readings, cell counts, protein, chloride and sugar content, cerebrospinal fluid, W.R. and Lange's curve. The pressure and manometric readings were normal. So was the rest of the laboratory examination of the C.S.F.

TABLE XIV

Analysis of C.S.F. in Chronic Manganese Poisoning Cases

Case No.	Proteins mgm.%	Increase in Globulins	Sugar mgm.%	Chlorides mgm.%	Cells (Lymphocytes per cubic mm.)	W.R.	Lange's Curve
1	30	No	62	710	2	Negative	0000000000
2	30	No	58	700	4	Negative	0000000000
3	60	No	56	680	3	Negative	0000000000
4	35	No	54	700	8	Negative	0000000000
5	25	No	58	700	6	Negative	0000000000
6	20	No	57	720	3	Negative	0000000000
797	30	No	60	720	4	Negative	0000000000
825	25	No	66	650	2	Negative	0000000000
889	40	No	63	730	1	Negative	0000000000

TABLE XV

Haemotological Analysis of Nine Chronic Manganese Poisoning Cases

Case No.	R.B.C.'s (millions/ cu. mm.)	Hb gms. %	W.B.C.'s (millions/ cu. mm.)	W.B.C. Differential Count %				Packed cell volume %	ESR in mm/hr.	Specific serologic tests (V.D.R.L. & R.M.T.	M.C.V. c/u/u	M.C.H. C%	Reticulocytes %
				Poly	Lymp	Eos	Mono						
1	4·10	8·6	8,500	43	34	22	1	33·0	—	Negative	80	26	1·8
2	4·50	14·0	8,800	55	23	20	2	41·0	10	Negative	90	34	1·0
3	5·20	14·6	4,900	70	19	8	3	42·0	4	Negative	80	34	1·0
4	4·30	13·0	6,700	69	15	12	4	40·0	45	Negative	93	30	1·6
5	5·50	16·0	11,100	64	18	14	4	41·0	10	Negative	90	32	0·9
6	5·30	15·6	14,900	53	31	13	3	49·0	9	Negative	92	31	0·3
797	4·65	15·0	5,800	63	20	12	5	44·5	—	Negative	95	34	0·4
825	5·50	15·4	5,600	50	40	10	0	48·0	7	Negative	87	32	0·2
889	5·15	14·2	6,800	51	37	8	4	47·0	18	Negative	91	30	0·2

(*h*) *The blood examinations* were carried out by the staff of the Haemotology Department of the J.J. Hospital, Bombay (Table XV). The red blood cell count was within normal limits in all the patients, except patient No. 1 who had 4.1 million cells/cmm. The Hb% was normal in all cases except again in patient No. 1, in whom it was 8.6 gms.%, consistent with an iron deficiency anaemia. It can thus be seen that in the small group brought over to Bombay, the blood Hb% and R.B.C. count did show a tendency to be higher than normal or on the high side of normal as noted on our extensive field studies at the mines themselves. The white cell count was normal. The differential white cell count confirmed our findings of eosinophila observed extensively amongst the miners of various categories and even in the random samples of the population in the neighbouring village. Only one patient had an eosinophilia of 4%, the rest showed figures going up to 20 and 22%. The total (absolute) eosinophilia count of the blood was also considerably higher than normal in all these cases.

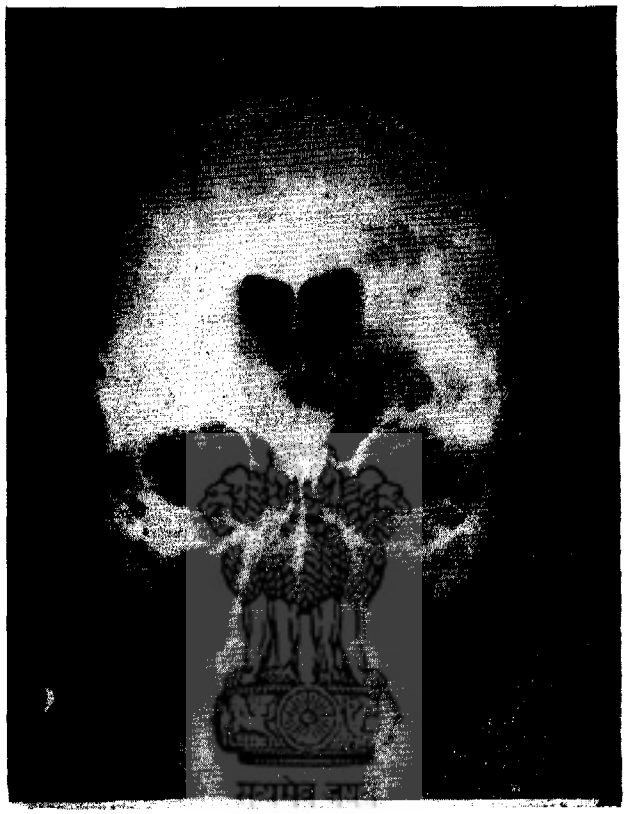
The packed cell volume, the mean corpuscular volume and the mean haemoglobin concentration revealed nothing specific for this disease. In the patient with the low red cell count and Hb%, a low M.C.V. and M.C.H. merely confirmed the iron deficiency type of microcytic anaemia.

The E.S.R. was within normal limits in all except one patient, in whom it was 45 mm in one hour. The reticulocyte count of the peripheral blood was normal in all cases.

(*i*) *Bone marrow examination* by a sternal puncture aspiration was carried out in all cases. The significant findings were again non-specific and considered of a slight eosinophilia. A typical report read as follows : "The marrow is cellular. The M.E. ratio is 2.5 : 1. Myeloid series shows normal differentiation. The eosinophils are slightly above normal. The plasma cells are normal. The erythroid series is normoblastic. Megakaryocytes are present, adequate and active".

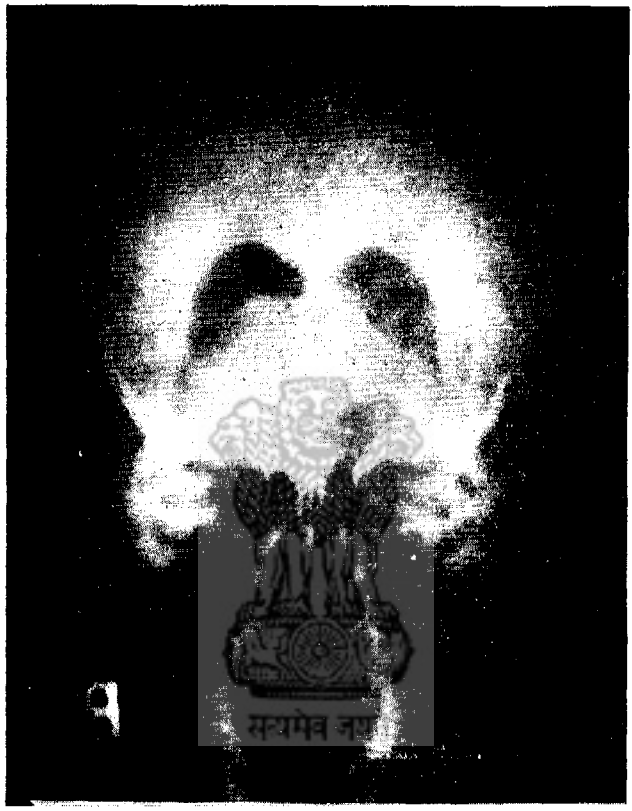
(*j*) *Lumbar air encephalography* was carried out in four of the nine patients (Figures XVI, XVII, XVIII—Case 797) and showed a normal sized symmetrical

Fig. XVI.



A.P. View of Case No. 797.

Fig. XVII.



P.A. View of Case No. 797.

Fig. XVIII.

Brow up Lateral View of Case No. 797.

ventricular system with no evidence of excess air in the subarachnoid spaces at the base or over the convexity of the brain. The air studies revealed no evidence of cortical, white or grey matter atrophy. As four of these patients showed no abnormality, this painful test was abandoned for the rest of them.

(*k*) *Electro-encephalographic* readings were made in all cases—in all the patients whilst they were awake and in most during sleep also. The tracings were normal in two and abnormal in the rest. The abnormalities which were non-specific, and again did not greatly help in the localisation of the lesion, were (*i*) an unusually low voltage with badly modulated alpha activity with a low alpha index; this was strikingly so in four out of the nine cases; in the low voltage tracings the voltage varied from 5 to 25 microvolts. (*ii*) Very little inter-areal difference in rhythm and voltage was evident in some tracings. (*iii*) In three cases there were well modulated 50 to 60 microvolts bursts of 5 to 7 c.p.s. activity. In one patient (No. 2) in whom the abnormality was maximum, the record showed such bursts both whilst awake, drowsy and during hyperventilation. the runs recurred every 4 to 20 seconds lasting for a few seconds (2 to 4 seconds) the longest run lasted 19 seconds. (*iv*) In two patients scattered (non-focal) spike activity was seen. (*v*) During sleep, the humps were badly formed in five out of nine patients. (*vi*) In over-breathing the cooperation of the patients was generally inadequate, but the notable abnormality was a very poor build-up of voltage.

(*l*) *Serum, Iron, Copper and Vitamin* B_{12} *estimation* : These were done with a view to find out if manganese had any specific effect upon the blood forming elements and also if it took part in or stimulated the iron metabolism. The normal serum iron for adult males in India as investigated and accepted by the Department of Haematology, J.J. Hospital, Bombay, where these investigations were done, varies from 80 to 175 micrograms %. A glance at Table XVI will reveal that in the first six patients, all fairly severe cases from Mine No. 1, the serum iron is well above the accepted higher normal figure. By contrast the three patients from Mine No. 9 who were not so severe cases, showed normal

TABLE XVI

Serum Iron, Copper and Vitamin B_{12} in nine Chronic Manganese Poisoning Cases

Case No.	Serum Iron in/μg/% Normal: 80—175 μg/(%) †		Serum Copper in /μg (%) (Normal : 40—250 /μgms (%)	Serum VitaminB12 in μ/μg/cc. (Normal-100—400 † μ μgms %)
1	190		89	90
2	285 (16-10-59)	260 (11-11-59)	83·33	88
3	145 (16-10-59)	105 (11-11-59)	Quantity of serum insufficient.	55
4	240 (16-10-59)	160 (11-11-59)	19·84	80
5	175 (16-10-59)	200 (11-11-59)	89·28	60
6	220 (16-10-59)	300 (11-11-59)	18·11	150
797	153 (12-7-60)		102	330
825	115 (12-7-60)		59	210
889	180 (12-7-60)		46	115
*20	106 (12-7-60)		68	150

*A doubtful case of manganism. † μg—Microgram.
†† μμg—Micromicrogram

serum iron content. The serum copper and serum Vitamin B_{12} estimations were within normal range. It appears then that serum iron is raised only in the more severe cases.

(*m*) *Manganese content estimation is Serum, Faeces, Urine and C.S.F.* : Estimation of trace elements in body fluids and tissues at the best of time is not an easy affair. Our task was made harder by the fact that no accurate assessments had been done in India by any laboratory of manganese content of body tissues. Hence the methods and materials were both new to us. Again we had to find a laboratory competent and willing and yet close at hand, to undertake this rather laborious task. Luckily, the staff of the Haffkine Institute, Bombay, through the kindness of their Director, were aggreable to set up the methods and equipment for the estimations. After initial trial and error, the colorimetric method was

found most suitable. The Haffkine report states "all methods, in principle, consist in oxidising manganous ions to permanganate and either directly reading the intensity of colouration or, where sensitivity is desired, utilising the permanganate formed to oxidise some reagent to give intense colouration. Out of the methods available we had to select the method that (1) gave reliable and consistent values, (2) was extremely sensitive to detect even traces of manganese present in normal persons, and (3) could be applied to small quantities of clinical material such as blood, C.S.F., etc." The report is given in Appendix III.

Manganese content of the serum, urine, faeces and C.S.F. are presented in tables with those of the controls of normal individuals accompanying them. These specimens were collected at the same time, under the same circumstances, with similar methods of collection of material, method of transport, and timing of samples for both the patients and controls. Some random samples of blood were also collected from blood donors and the manganese content estimated. This gave us many readings in normal individuals to compare with the manganese intoxication cases.

No striking information was available from this study. However, after the initial difficulty of setting up the proper method of estimation and standardising the methods of collection so as not to cause external contamination (even through the collecting needle) we have been able to collect a mass of figures both in the patients and control, which would give us the normal range of manganese content of various body fluids in the human.

The urinary manganese (Table XVII) varied from 0.39 micrograms in 10 ccs., (Patient No. 2), to 3.92 micrograms in 10 ccs. (Patient No. 4). However, a glance at the table will show that the urinary excretion of manganese has fluctuated considerably on different days even in these two patients. The controls showed the lowest reading of 0.61 micrograms and highest of 2.29 micrograms, both in the same person but on different days—the other controls showed fluctuating figures in between these ranges.

TABLE XVII

Manganese Content (in Micrograms) in Urin (10 c.c. samples; 24 hours samples underlined) before and after oral E. D. T. A. Administration—Miners showing Manganese Poisoning.

Case No.	Before E.D.T.A.			After oral E.D.T.A.			After intravenous E.D.T.A.	
	Date	Value		Date	Value		Date	Value
1	26-5-60	1·05	(128·1)	21-6-60	0·80			
				4-7-60	0·95	(113·3)		
2	27-10-59	0·50						
	30-10-59	1·62						
	16-11-59	0·39	(46·6)	19-12-59	0·85			
				21-12-59	0·70			
3	27-10-59	1·57						
	30-10-59	1·34						
	16-11-59	0·58	(124·5)					
4	27-10-59	1·18						
	30-10-59	3·92						
	16-11-59	2·24	(199·0)					
5	27-10-59	0·67						
	30-10-59	0·90						
	16-11-59	0·90	(95·0)	19-12-59	1·00			
				21-12-59	0·60			
6	27-10-59	3·69						
	30-10-59	3·24						
	16-11-59	0·95	(105·5)	19-12-59	1·50			
				21-12-59	1·15			
	26-5-60	0·80	(70·8)	21-6-60	0·90			
				4-7-60	1·15	(124·0)		
20	26-5-60	0·80	(46·2)					
797	14-5-60	1·15						
825	10-6-60	1·10	(143·0)	4-7-60	1·10	(112·0)		
889	10-6-60	1·60	(114·0)	4-7-60	1·25	(142·0)		

CONTROLS

Control Nos.			
1	27-10-59	0·61	
	10-10-59	2·29	
	16-11-59	0·90	(117·5)
2	16-11-59	1·12	(180·9)
3	27-10-59	0·80	
	30-10-59	1·68	
4	19-12-59	0·85	
9	19-12-59	2·00	

One of us, Dr. T. P. Niyogi, together with Professor S. L. Goswami of the Department of Pharmacology, Medical College, Jabalpur, carried out estimation of urinary manganese of workers exposed directly to dust at the site. The estimation revealed that the manganese in urine was much higher in those directly exposed to dust than those away from the mines. Animal experiments were also carried out and a rise in urinary manganese was found in those animals exposed to manganese dust as opposed to the controls. This corroborates the findings on humans.

The nine cases who were brought to Bombay, however, showed no rise in urinary manganese. This was perhaps because they were away from mines for a few months to a few years.

After Calcium EDTA and Parpanit had been given orally, no excessive excretion of manganese was noted in the urine, immediately or a fortnight after the stoppage of the drug. This is discussed later.

Serum Manganese : The serum manganese ranges varied from 0.46 microgms in 5 mls (Case No. 2) to 1.75 microgms in 5 mls (Case No. 3). In the control group the range was wide: from 0.50 microgms in 5 mls to 2.6 microgms in 5 mls.

The most striking finding in all the manganese estimations was observed in patients whose serum was estimated before and after administration of Calcium EDTA orally (the dose varied from 500 mgm TDS for 7 days in patients 2, 4, 5, 6 to 5 gms. daily for 10 days in patients 1, 6, 797 and 825 (Table XVIII). In all of them there was an appreciable rise of serum manganese immediately after administration of the drug. The rise varied in different patients regardless of the dose of the drugs from 0.28 microgms. to 2.55 microgms. The latter rise was nearly three times the original manganese level in the serum before administration of EDTA.

The rise in serum manganese after administration of EDTA orally was so striking in all patients that we decided to do a small control trial on four normal persons. 500 mgm. of EDTA was given three times a day orally for 10 days and serum estimation for manganese was done before, mid-way and at the end of the course and 10 days after the end of the course to see if there was any rise of serum manganese as seen in the patients. No such rise was noted.

Surprisingly, however, two patients (No. 1 and 825) were given intravenous EDTA 2.5 gms. in 500 ccs saline for 6 days (drip method) and the serum estimations were done before,

TABLE XVIII

Rise in Serum Maganese after E.D.T.A. administation (values in micrograms for 5 ml. serum) Miners showing Manganese Poisioning

Case No.	Before E.D.T.A.		After oral E.D.T.A.		After intravenous E.D.T.A.		
	Date	Value	Date	Value	Date	Value	
1	26-5-60	0·86	21-6-60	1·14			
	19-8-60	2·10			23-8-60	1·08	(During)
					25-8-60	0·95	(After)
					6-9-60	2·49	(After 10 days)
2	3-12-59	0·46	21-12-59	1·25			
3	28-11-59	1·75					
4	4-12-59	0·50	21-12-59	2·40			
5	4-12-59	1·00	21-12-59	2·55			
6	4-12-59	1·25	21-12-59	3·25			
	26-5-60	0·85	21-6-60	3·40			
	13-8-60	0·75					
20	26-5-60	0·90					
797	10-5-60	1·40					
825	26-5-60	1·00	4-7-60	1·87			
	13-8-60	0·99					
	19-8-60	1·75			23-8-60	1·40	(During)
					25-8-60	0·95	(After)
					6-9-60	0·94	(10 days after)
889	26-5-60	1·10	4-7-60	2·15			
	13-8-60	1·00					

CONTROLS

Control Nos.				
4	4-12-59	0·70		
5	4-12-59	2·35		
10	10-5-60	0·50		
11	14-5-60	1·56		
12	14-5-60	2·56		
14	4-8-60	2·20		
15	4-8-60	2·24		
16	4-8-60	2·60		
17	4-8-60	2·50		
18	4-8-60	1·50		
19	27-8-60	1·50		
20	27-8-60	2·18	31-8-60	1·43 (During)
			15-9-60	1·09 (After 10 days)
21	27-8-60	1·70	31-8-60	1·20 (During)
			5-9-60	1·55 (After)
			15-9-60	1·05 (After 10 days)
22	27-8-60	1·21	31-8-60	1·25 (During)
			5-9-60	1·00 (After)
			15-9-60	1·16 (After 10 days)
23	27-8-60	1·76	31-8-60	1·90 (During)
			6-9-60	1·34 (After)
			15-9-60	1·75 (After 10 days)

mid-way and after the end of the course, and 10 days after the end of the course. No rise in serum manganese was found, although when these same patients were given the EDTA orally, the rise was remarkable. We have no explanation for these facts.

Manganese in the Cerebrospinal Fluid : The CSF manganese estimation in patients varied from 0.42 to 3.1 microgms per 5 mls. In controls the figures varied between 1.06 and 2.34 microgms in 5 mls. There was no sharp variation in readings before and after EDTA. (Table XIX).

TABLE XIX

Manganese Content (in micrograms) in the cerebrospinal fluid (5 ml. samples) before and after oral E.D.T.A. administration— Miners showing Manganese Poisoning.

Case No.	Before E.D.T.A.		After oral E.D.T.A.		After intravenous E.D.T.A.	
	Date	Value	Date	Value	Date	Value
1	26-5-60	0·75	21-6-60	0·65		
2	3-12-59	1·32				
4	3-12-59	1·15				
5	7-12-59	3·10				
6	4-12-59	0·42				
	26-5-60	1·75	21-6-60	1·10		
20	26-5-60	1·70				
797	10-5-60	1·16				
825	11-6-60	1·60	4-7-60	2·2		
889	21-6-60	1·15	4-7-60	3·0		
		CONTROLS				
Control Nos.						
4	7-12-59	2·10				
7	8-12-59	1·10				
10	10-5-60	1·30				
11	14-5-60	1·44				
12	14-5-60	2·34				
13	14-5-60	1·06				

Faecal Manganese : (Table XX). This was estimated in 1 gm. of wet faeces and the readings amongst patients varied from 9.7 microgm per one gram of wet faeces to 41 microgm/gm. The controls' lowest and highest readings were respectively 12.70 and 17.60 microgms/gm wet faeces. Administration of EDTA caused no dramatic rise or fall.

TABLE XX

Manganese Content (in micrograms in one gram samples in faeces) before and after oral E.D.T.A. Administration—Miners showing Manganese Poisoning.

Case No.	Before E.D.T.A.		After oral E.D.T.A.		After intravenous EDTA	
	Date	Value	Date	Value	Date	Value
1	26-5-60	41·00	21-6-60	17·2		
			4-7-60	16·0		
2	4-12-59	15·00				
3	3-11-59	18·00				
4	23-11-59	16·80				
	4-12-59	15·20				
5	23-11-59	17·25				
	4-12-59	9·70	21-12-59	14·7		
6	23-11-59	17·20				
	4-12-59	16·00	21-12-59	12·8		
	26-5-60	26·14	21-6-60	34·6		
20	26-5-60	19·00				
797	14-5-60	22·37				
825			4-7-60	29·54		
889			4-7-60	25·90		

CONTROLS

Control Nos.		
1	23-11-59	16·7
2	23-11-59	15·9
6	4-12-59	12·7
8	7-12-59	17·6

(*n*) A—*Quantitative estimation of blood* :

(*i*) Copper oxidase,

(*ii*) Alpha ketoglutarate,

(*iii*) Pyruvate and lactate.

B—*Chromatographic observations on aminoacids in blood and urine* :

C—*Chromatographic observations of urinary organic acids*:

The above tests were undertaken for two reasons: (*i*) To find out whether the known clinical and pathological similarities between manganese intoxication (exogenous) and Wilson's disease (endogenous copper metabolism disorder) also extended to the biochemical investigations of the disease. The tests for these were quantitative serum copper oxidase estimation and chromatographic study of blood and urinary aminoacids. In Wilson's disease low serum copper oxidase and aminoaciduria are consistent findings. (*ii*) To study and see if there was any gross generalised disturbance in carbohydrate or oxidative metabolism, as manganese is known to go into complex chemical combination with intracellular Organelles such as mitochondria (Cotzias, 1958). The tests for these were the quantitative estimation of blood alphaketoglutarate, pyruvate and lactate and chromatographic observations of the urinary organic acids.

TABLE XXI

(*i*) *Quantitative Estimations in Blood*

Case No.	Alpha-keto-glutarate mgm.%	Pyruvate mgm.%	Lactate mg. %	Copper	Oxidase Optical Density Units Ravin's
2	0·30	1·31	7·34	0·14	
3	0·34	1·38	7·45	0·28	
4	0·40	1·34	6·52	0·12	
5	0·23	1·47	6·27	0·17	
6	0·54	1·36	5·47	0·13	
Normal	0·10—0·34	0·80—1·70	5·0—15·0	0·10—0·40	

Pyruvate, lactate and copper oxidase are within normal limits. Although in two of the subjects the alpha-ketoglutarate is somewhat higher than the normal values, not much significance can be attached to this isolated observation.

(*ii*) *Chromatographic Observations*

(1) *Amino acids* : In amounts of blood normally spotted on paper chromatograms (250λ) and when compared to the aminoacids in identical amounts of blood from control subjects, this batch of patients showed a generalised decrease in the blood aminoacids. In the urine of these 5 patients a normal pattern of aminoacids was discerned. For the group as a whole, again as compared to a group of controls, there was a suggestion of increase in the excretion of most of the aminoacids. This was clearly noticeable, however, only in the case of glutamine and methionine and this cannot be considered to be a gross generalised aminoaciduria.

(2) *Organic acids*: The urine was also chromatographed for some of the Kreb's cycle acids, phenylic compounds and other organic acids, by a paper chromatographic technique. In both their distribution and their rough quantitation, the organic acids in the patients' urine were comparable to those in the urine of controls.

(The above investigations were carried out by Dr. D. K. Dastur, Neurology Department, Indian Council of Medical Research, Bombay).

Conclusions

The various investigations carried out have led us no further into understanding the exact mechanism of the disease. The abnormal findings were mostly non-specific, for example, the E.E.G. records. The relatively high Hb content and red cell count and the rise of serum manganese after oral administration of EDTA are worth noting. The high eosinophilic counts are probably of no significance.

CHAPTER VI

Manganese is an essential element for normal plant and animal nutrition. A man takes in an average of 5—10 mg. of manganese daily by way of his food and drink. So the human system is not unaccustomed to the manganese metabolism. It is only when excessive amount of the metal is absorbed and the balance between the intake and elimination is disturbed that poisoning may occur. Manganese can get into the body by way of the alimentary tract or through the pulmonary route. Absorption of the metal when ingested even in large quantities is poor. In industrial exposure, it is really the pulmonary tract which plays the major role in the absorption of manganese in the body system.

The body tries to get rid of the excess manganese that reaches the general circulation. The liver plays an important part in excreting manganese into the bile from where it is eliminated through faeces. A large proportion of manganese is thus excreted in the faeces. Other routes of elimination are urine and hair.

Manganese poisoning and the hazards to the health of workers in manganese mines and in other industries where manganese is constantly employed directly or indirectly in the manufacture of various products have been known for over a century. Whilst it is known that drillers, being more exposed to dust inhalation, are more effected by this condition, loaders, driller helpers, sorters, packers and those who sieve the ore can also be affected. Cases have also been reported during production of ferro-manganese. Although the cause of individual susceptibility is not known, only a few amongst a large number of exposed workers are known to be affected. It has also been known that the respiratory and the nervous systems bear the main brunt of poisoning.

To Couper, a Frenchman, goes the credit of describing the first five cases in 1837. These men were employed in grinding manganese dioxide in the manufacture of chlorine for bleaching powder. We have no access to the original paper but to quote from Donald Hunter's book of Diseases of Occupation (1957) —Couper wrote as follows:—

> "Their skin is constantly covered with a layer of the oxide, and the air which they breathe is impregnated with a multitude of molecules of this oxide which

are introduced into their lungs by respiration. In 1921, a young man apparently in good health, being employed at this work, presented symptoms of paraplegia which, becoming worse, forced him at the end of some months to stop work. After having tried without effect the medicines used in paralysis, he absented himself from the neighbourhood for a year, and at the end of this time, having returned, it was evident that he had made little progress towards recovery. In the following year another workman, similarly employed in grinding manganese and apparently enjoying the best health, fell equally ill. It not being suspected that manganese produced poisonous effects, he was permitted to work for several months, with the exception of short intervals employed in treatment. As the paralysis increased, manganese was finally suspected to be the cause and the workman moved to another region. After this time there was no augmentation of symptoms and at the end of six years the patient was in good health. During the height of the disease, the weakness of the contractile muscles was much greater in the legs than in the arms. It was of such nature that the patient reeled in walking and leaned forward when he wished to walk. The arms were somewhat weak and there was difficulty in speech. He was not able to make himself understood by a person at a little distance. Other sensations and intelligence were unaffected. The trunk muscles had the appearance of a paralytic. Saliva ran from the mouth during speech. There was no trembling of any part of the body, or colic, constipation nor derangement of digestion. He was given mercurials, vesication of the head and dorsal spine and strychnine, but all without effect."

Subsequently nothing further was written till Von Jaksch described three cases in 1901 from Austria and in 1919 Edsall, Wilbur and Drinker from the U.S.A. In England, Charles, first, pointed out this condition in 1922 and wrote an excellent paper on seven cases in 1927. Hunter mentions (1957) that "at least seventy-four more cases have been published since 1945 so that the disease can no longer be called very rare". Whilst agreeing with Hunter that the disease is not rare any more, we would like to point out the excellent clinical paper of Rodier (1955) reporting 150 cases from workers in manganese mines in Morocco. All were underground workers, and of these 132

were drillers. The 18 other workers were doing jobs in proximity to the drillers. Garcia Avila and Penalver (1953, 1955) reported cases of manganese poisoning in the mines of Cuba. The first cases to be detected in our country were reported by Niyogi (1957) and later on this same material studied by Berry and Bidwai (1959). However, whilst these studies were of great value, they did not span the breadth of the problem on a nationwide scale.

Pre-Manganism : Most of the symptoms and signs seen by us have been noted by the previous workers. The peculiar gait, retropulsion, the masklike face, pathological laughter and the low monotonous speech have in fact formed the basis of diagnosis of this condition for over a century. This, however, is the description of the late manifestations of the disease. Charles observed that asthenia and mental and bodily fatigue were also distinctive manifestations of the disease. It was Rodier, however, in 1955 who set about to define the early symptoms and manifestations of this disease, with a belief that if the patient was isolated at this stage, no neurological deficit would appear, or if present, it would be in a reversible stage, allowing for complete recovery if removed from exposure to the dust. He coined the word 'pre-manganism' or the prodormal stage of the disease. He laid special stress on anorexia, asthenia, slowness of body movements, apathy, depression, lack of concentration, mental instability, cramps, headache and sleep disorders as early symptoms of the disease. He also found that a large number of patients at the onset of their disease developed increased sexual drive and need for sexual fulfilment but that nearly 80% became impotent a short time later. He mentioned that at times acute psychosis may herald the disease. He urged that patients must be diagnosed at this stage of symptoms only even before the physical signs appeared and be removed from their occupation. The next two stages of development of the disease according to him are the intermediate and established phases.

We have also noticed that the symptoms mentioned above certainly precede the physical disabilities by a few weeks to a few months depending on the progress of each individual's disease. It is difficult to explain the mechanism of these various symptoms in terms of localisation of the lesions to a specific organ of the body, and to find pathological corroborations at autopsy. Thus, do asthenia, anorexia, impotence, temporary insanity, depression, mental instability, sleep disturbance occur from some temporary disturbances of the brain mechanism ? This may be due either to a reversible structural damage or only a biochemical disturbance, disappearing with withdrawal from further exposure to the dust. The most likely cerebral site of

such a disturbance would be the frontal lobes, but interestingly enough if this was so, no defect of intellect or memory was detected in any of our cases at any stage of the illness except those reported to have occurred during the bouts of psychosis in some of our patients. The explanation of backache, muscle cramps, general body pains and aches is also not easy to come by if believed to be due to direct effect of manganese on the various body tissues.

On the other hand whilst not doubting the usefulness of these early warning signals of a more serious condition to follow, we feel that at least with our patients in India, there is reason to evaluate these symptoms cautiously. We found evidence of obvious maganism in the two underground mines only, but it was in only one of them (Mine No. 1) that we found cases whom we have labelled as "doubtful" manganism. On the other hand, we feel that it is crucial to note that hysterics, neurotics and malingerers can easily simulate the symptoms, and in the absence of signs of the disease it would be hard to say which patients were suffering from pre-manganism and which were not. This, though it may seemingly be an unimportant situation, is very vital from the point of view of the work output of each mine. If every miner who complained of anorexia, asthenia and one or two other symptoms, in spite of having no physical signs, is put off work, the mining industry may suffer considerably. As an example, one of the workers, No. 20 who was labelled as a case of pre-manganism for the last three years has continued to do drilling at Mine No. 1 and although he complains of lassitude, anorexia, asthenia, etc. no evidence of manganism is forthcoming clinically. We are not aware of, nor are there any definite reports in literature of the exact period after which overt signs of manganism follow pre-manganism. Is this patient then a neurotic or has he gone on in a stage of pre-manganism for well over three years? Should he be taken off work against his own will to continue? Should he be on full pay or be given compensation as having been afflicted whilst at work?

We see no easy solution to the problem—each case has to be decided on its merit. Whilst the worker's health is to be protected it must be seen that the industry is safeguarded from those who might take advantage of such a situation by malingering. We feel that under such circumstances when a worker complains of symptoms which could suggest pre-manganism, he should be examined by a competent medical officer periodically and at once taken off work the moment the first evident signs of the disease appear. We believe even at that stage the disease is still reversible. Such procedure would at the same time

safeguard the industry from malingerers and neurotics. Further recommendations will be suggested later.

Both Rodier and Penalver have touched on the problem of malingerers in their papers.

Pathology : The overall neurological picture has been described as a variety of Parkinsonism. Whilst this is broadly true, there are very many differences in details. In the other varieties of Parkinson's disease, either rigidity or tremor or both, specially of the upper limbs form a main feature of the disease; in manganism neither rigidity nor tremors are seen with any degree of consistency and even so are very mild (Tables VII, VIII, IX & X). At best there is a fine or coarse tremor of the outstretched fingers and the severe or characteristic Parkinsonism tremor has never been noticed by us. The rigidity of limbs is not evinced whilst lying down except that as mentioned before some increase in tone specially at the ankles, was found in a few cases. But when the patient was made to walk, the gait suggested a distinct and marked increase in tone of the lower limbs. The knees became stiff, a tendency to scissoring developed (due to increased tone of the adductors of the thigh) and the heels were raised off the ground—an obvious condition of extensor hypertonia of the lower limbs. This is certainly due to an increase of tone which is associated with posture and the fact that the patient has stood upright. Denny Brown (1960) in his Croonian Lectures on "Diseases of the Basal Ganglia" made a broad distinction regarding the basis of increased tone. He divided them into two large groups—those in whom the tone was increased as a result of an exaggeration of the normal plastic tonus of the body or the lengthening and shortening reaction as in cases of paralysis agitans and the other common varieties of Parkinsonism, and those due to an increase in the extensor hypertonia related to the anti-gravity reflexes characterised by decerebrate rigidity. He also mentioned that the one variety may merge into the other. In our cases the increased tone appears to be more from the latter type of an exaggerated anti-gravity reflex appearing only when the patient stands up and may be vestibular in origin. From the beginning of our study we had observed and felt that this unusual change of tone was due to a lesion or some other functional disturbance at the level of the upper mid-brain, akin to that in a patient with decerebrate rigidity. The Croonian lectures of Denny Brown have convinced us more of our hypothesis.

This altered tonus of the body on standing up also explains the mild propulsion, the unusually marked retropulsion and the tendency to fall backwards on the slightest push like a log stand-

ing on one end (as also noticed in his cases by Charles). The abnormal attitude and the rigidity of the whole body on standing up disturbs the centre of gravity and the patient is unable to correct it, so that he totters backward or forwards (more backward in our cases) in the direction of the push trying as it were to run after his centre of gravity. In the more severe cases the slowness of movements and the rigidity prevent the patient from taking even a step backward and in his attempt to do so he disturbs his centre of gravity and falls like a rigid beam in the direction of the attempted movement.

Pathological laughter and more unusually weeping have been noted by all authors who have studied this disease. It has been observed by us also and is typical of this condition. It is a characteristic unmistakable laughter which is seen in no other form of Parkinsonism. Pathological laughter or 'sham mirth' have been described in several other diseases of the nervous system but the high pitched laughter ending in a crowing sound is noted only in manganism. There has been much discussion in the literature (Martin, 1950; Ironside, 1956) on the 'centre of laughter' if such a centre exists at all. Foerster and Gagel (1933) were amongst the first workers to note accidentally the relationship of the hypothalamus and the floor of the third ventricle with laughter. Whilst operating on an inter-ventricular cyst, Foerster was trying to swab blood off the floor of the third ventricle, when the patient burst out laughing and made hilarious obscene remarks. As soon as the manoeuvre was stopped from the near region of the floor of the third ventricle the patient became quiet. Every time the surgical manoeuvre was repeated the sham mirth appeared. Many other workers have had the opportunity of studying at operation or at autopsy cases of tumors or aneurysms indenting the floor of the third ventricle, in whom attacks of causeless, meaningless and excessive laughter formed a dominating feature of the disease. Pathological laughter is also noted in cases of pseudobulbar palsy as in generalised cerebro-vascular disease, motor neurone disease or disseminated sclerosis when there is impaired function of both pyramidal tracts. When laughter occurs from such conditions other evidence of pyramidal damage is obvious. The hypothesis at present regarding the physiological basis of laughter is that the posterior part of the hypothalamus *i.e.* the floor of the third ventricle just anterior to the mammillary bodies is associated in some way with the normal mechanism of laughter, and that the pyramidal and frontal fibres exert some form of control over it, so that laughter occurs under appropriate conditions and in proportion to the stimulus; and the physical expression of laughter is proportionate to its emotional content.

In either lesion of the pyramidal tracts, the voluntary control for laughter is released. In lesions of the floor of the third ventricle an excitation process, of the centre itself, exists and gives rise to disproportionate laughter, so that a mere smile of greeting may bring forth peels of laughter from the patient, or the patient may laugh when the situation demands complete sobriety. Often the physical expression of laughter is not accompanied by any pleasurable feeling to the patient; in fact, the patient feels most unhappy and embarrassed whilst laughing. This was so in almost all our cases. We feel that the lesion in manganism is more likely to be in the posterior part of the hypothalamus than in the pyramidal tracts, because in many of the patients who have pathological laughter no pyramidal signs were seen elsewhere and in no patient was there other evidence of pseudobulbar palsy. Again, our hypothesis explaining the abnormal tonus to be due to a lesion at the upper mid-brain level, mutually supports the localisation of the lesion for explaining pathological laughter in the adjacent hypothalamus. However, no other signs of hypothalamic disease like obesity, polydypsia, etc., were present—probably because the anterior hypothalamus is not involved.

The slowness of movement, the fixed mask-like face, the low monotonous speech, the micrographia and the occasional tremor must be due, by analogy with other forms of Parkinsonism, to lesions of the basal ganglia and its connection including the substantia nigra.

Slight impairment of function of the pyramidal tracts has been mentioned by other authors, and we found clinical corroboration of this in a few of our cases. The weakness of grip and generally of the limbs is hard to explain as it is present even in those who show no pyramidal signs. Is it just due to slowness of co-ordinated movement or a part of the generalised asthenia which may be arising from a mild impairment of frontal lobe functions? We have discussed previously the possibility of the probable early symptoms of the disease manifesting as a mild disturbance of frontal lobe function.

From the above, we thus conclude, albeit on clinical observations only, that the main lesions of manganism are closely adjacent to each other in the brain. The basal ganglia (the mask-like face, monotonous speech, and slow movements) the posterior hypothalamus, (pathological laughter) and the upper mid-brain (the altered tonus with retropulsion, propulsion and backward fall) seem to be affected in every case of manganism and explain the main manifestations of the disease. In some, the adjacent pyramidal tracts may also be involved. The

involvement of the frontal lobes to explain the symptoms of asthenia, mental irritability, etc. remains even on theoretical grounds in doubt. The investigations carried out by us were of no great help in accurate localisation of lesions. Air encephalography performed in four patients revealed no evidence of ventricular dilatation or cortical atrophy (Figures XVI, XVII & XVIII). However, if the lesions were not severe enough, ventricular dilatation from cerebral atrophy would not be seen. Electro-encephalography done in every case showed a few abnormalities, which though non-specific corroborated the clinical diagnosis, of lesions of the deeper mid-line structures of the cerebral hemispheres and the upper mid-brain.

We have no post-mortem evidence to corroborate our clinical and theoretical localisation of the lesions of this disease. The only available post-mortem reports are contradictory to each other. Canavan, Cobb and Drinker (1934) did an autopsy on a manganese miner who died of an unassociated cardiac complaint when he was 69, after 14 years of suffering from disabilities due to manganese poisoning. They found atrophy of the frontal lobes of the brain and the basal ganglia with some dilatation of the ventricular systems. Histological examination revealed degeneration of the nerve cells of the basal ganglia and optic thalamus with some gliosis. On the other hand, Flinn et al (1940) found very little change in the brain at post-mortem of their case. Experiments on animals have been conducted by H. Mella (1924), and L. Van Bogaert and Dallamagne (1943; 1945). Mella administered manganese chloride orally for over 17 months to monkeys giving a total dose of 2,980 mgm. He was able to produce in animals a picture at first of chorea and finally of Parkinsonism which he attributed to cellular changes in the corpus striatum. Autopsy examination of the brain revealed sclerosis and pyknotic changes in the cells of the putamen and caudate nuclei with vacuolation of the larger cells. At places there was gliosis and the 'Putameno-Caudate' fibres had lost their myline sheath. The cerebellum was normal. No manganese was detected in the brain, but he found evidence of hepatitis and presence of manganese in the liver, kidneys, marrow and the reticulo endothetial system. L. Van Bogaert and Dallamagne did extensive and careful study on animals, by intoxicating them with manganese by aerosol inhalation. They were unable to corroborate the findings of Mella. The animal showed signs of severe cerebellar dysfunction with ataxia, wide based gait and intensive tremor; later on actual paralysis of the hind quarters appeared. There was not much clinical evidence of basal ganglia disorder and no Parkinsonism was noticed. At autopsy the lesions were found scattered all over the nervous

system, including the spinal cord, but the most severe damage was to the Purkinje cell and granular cell layers of the cerebellum. The monkey was studied for nearly six months before being sacrificed and Van Bogaert found no evidence of manganese in any body tissue including the lungs. He maintains that in six months the elimination of manganese from the body is complete, although irreversible damage has been done.

It thus appears that our attempt at localisation of lesions must rest purely on clinical grounds in the absence of sufficient autopsy reports on humans on reproduction of the syndrome in experimental animals.

Pathogenesis : Except for the autopsy reports of Canavan et al and the experiments of Mella actual structural damage has, therefore, not been demonstrated in the brain in manganism. There are those who believe, and with some reason, that manganism produces its neurological symptoms initially at least not by a structural destruction of the brain but by a continual, biochemical disturbance. The supporting evidence is that (1) even when the full syndrome has developed, immediate withdrawal from further contact with dust results in a recovery. The lesions under these circumstances must have been probably from a functional disturbance of certain parts of the brain, as structural damage to nervous tissue would not have recovered so quickly. Also Van Bogaert found that the nervous manifestations in the monkey disappeared if the intoxication by manganese was withdrawn in three weeks. (2) Penalver (1957) reported albeit a single case, of successful reversal of symptoms and signs of a longstanding case of chronic manganism by prolonged treatment with calcium, disodium, ethelene-diaminetetracetate (E.D.T.A.). Again, this means merely a removal from the blood of circulating manganese by its forming a chemical complex with the above drug. It would be impossible to reverse changes of structural damage to the brain by mere administration of E.D.T.A. We have not been able to produce any improvement in our patients either with oral or intravenous calcium E.D.T.A. (3) Again, as Cotzias (1958) mentions in his article, "there does not seem to exist well documented evidence of an increase of this metal's concentration in the brains of the of victims of this disease." On the contrary, there exists evidence in such a case (Flinn et al, 1940) which suggests that both the concentration as well as the partition of the metal in the tissues other than the lung is normal. (In normal rabbits Fore Morton (1952) found that the distribution of manganese in the various organs was the same, without any predeliction for the lung).

The mechanism of the production of the symptoms is, therefore, believed by some to be due not to anatomical deposit of

manganese in the brain and subsequent damage to the brain, as for example, from copper deposits in Wilson's Disease, but due to a continuous and rapid perfusion of the brain with a complex organic manganese compound. The abnormal symptoms are being produced by biochemical disturbance of certain parts of the brain. In manganese intoxication cases, as the only organ where manganese has been found in large quantities in the body is the lung (Flinn et al) it is postulated that lung is the repository of large amounts of inhaled manganese and that a toxic manganese compound is formed there and later circulated in high concentration to the rest of the body including the brain. What this theory cannot explain easily is the existence of the disease several years after removal from exposure to the dust. It is not made clear from the available literature whether the continued manifestations of the disease syndrome are due to either (1) stores of manganese in the lungs large enough to perfuse the brain for several years if not for a lifetime without replenishment or (2) that after perfusion of the brain by a circulating manganese compound for a certain period (hitherto unspecified), irreversible structural damage appears in the brain, without manganese being actually deposited in the brain itself. This latter theory would also explain reversal of the syndrome if the dust exposure has been stopped. If the former theory were true, at some stage, say 10 years after removal from exposure, the disease manifestations must get less and less ultimately disappear as the lung depots are not continually replenished by fresh stocks of maganese dust. A ten or fifteen year or longer follow up examination of some of our cases removed from the mines would answer this question.

Manganism and Lathyrism

During the course of our investigation we came across a problem which is entirely indigenous to our country and not met with by other investigators in the field in other countries (Shourie 1945).

As pointed out earlier, there was a group of patients who had symptoms and signs of a progressive, pure motor paraplegia with no involvement of the body above the waist. The question was : were these cases of primary lateral sclerosis of either indeterminate aetiology or due to lathyriasis or could these be conceivably a variant of chronic manganese poisoning affecting the nervous system *i.e.* could manganese have an effect only on the spiral pyramidal tracts and not affect the cerebrum as in the classical cases? We are in no position at the moment to give an unequivocal answer to this question. The four major points against these cases being true manganism are :

(1) In classical manganism seen by us and reported by others pyramidal tract affection is either non-existent or only very mildly evident, even when the rest of the picture of the faces, speech, laughter, etc. is very advanced.

(2) Reports from Cuba and Morocco, where large number of manganese cases have been reported, mention no cases of primary lateral sclerosis as one of the forms of manganese intoxication. Lathyrism does not exist in these countries.

(3) Out of the seven cases, four were from Mine No. 10 where no cases of the classical syndrome were seen by us. It is unlikely in an opencast mine with excellent ventilation that manganese intoxication should exist, as has been our experience (discussed elsewhere in the report). It then follows that these four patients with primary lateral sclerosis could hardly be due to manganism.

(4) Lathyrism, a form of primary lateral sclerosis, is known to be widespread among the general population in the districts (in Madhya Pradesh) where the mines are found. It is quite possible that the patients showing pure pyramidal signs were sufferers from lathyrism who were employed coincidentally in manganese mines.

However, even with such clear arguments supporting the contention that these are sufferers from lathyriasis, there are two very strong points supporting exactly the opposite view, that these cases of primary lateral sclerosis among miners are a variant, albeit unusual, of manganese intoxication.

There are three cases (Nos. 845, 870, 889) from Mine No. 9 who have been accepted by us after careful consideration as cases of manganese intoxication, whose physical handicap at present is only that of pyramidal tract disorder of the lower-limbs. The abnormal faces, speech or laughter do not exist, although retropulsion and propulsion are evident. They have been labelled as cases of manganism because of history of asthenia, anorexia, impotence and in one case, occasional pathological laughter. In all of them a history of a transitory episode of mental imbalance was available. All these symptoms are known to be associated with manganism. In the absence of history and the retropulsion it would be very difficult to differentiate them from early cases of primary lateral sclerosis (Lathyriasis).

The Indian Council of Medical Research Committee on "Lathyriasis" is making a searching enquiry (I.C.M.R. Report, July 1959) into a proposed theory that lathyriasis is a form of

manganese intoxication due to ingestion of lathyrus sativus which has a deleterious effect on the nervous system by its high manganese content. The evidence that this widespread disease, in certain parts of India, is due to ingestion of this "dal" is now incontrovertible but the exact mechanism of its toxic action on the nervous system has not so far been discovered. Dr. Sadasivan's unit in Madras has analysed certain forms of lathyrus eaten regularly and found them to be rich in manganese content. Several investigations in humans and animals and also a closer chemical study of the 'Lathyrus' and the soil in which it is grown have been vigorously started to explore this new hope of discovering the aetiology of this crippling disease. Whilst it is obvious that classical manganism presents quite a different picture to lathyriasis the possible link with which we agree is suggested in the I.C.M.R. report (1959). To quote the report,

"Manganese is known to be neurotoxic. However, the symptoms of chronic manganese intoxication in the human subject are similar to Parkinsonism and quite different from the clinical picture of lathyrism. The point has to be remembered however, that unlike in chronic manganese intoxication wherein manganese is inhaled, the consumption of lathyrus results in an ingestion of large amounts of manganese; also the form of manganese ingested in the case of lathyrism may be different from the form in which it is inhaled in chronic manganese intoxication. It would appear, therefore, that the possibility of manganese intoxication playing a role in the pathogenesis of lathyrism would merit exploration".

Whilst leaving the question unanswered as to whether those seven cases of primary lateral sclerosis in the workers were due to manganism or lathyrism, in view of the link discussed above between the two, it is possible that these seven patients may be those on whom the toxic effect of manganese has worked by the manganese being ingested, and absorbed via the gut rather than inhaled and absorbed as a different compound through the alveolar membrane as in the classical cases. If this was true then it provides a support to the theory of lathyrism being due to manganese toxicity. In fact lathyrism would be relabelled as "lathyro-manganism".

In conclusion, we prefer to consider these seven cases as those of primary lateral sclerosis of as yet indeterminate etiology. It is possible that the four patients who gave an outstanding history of intake of the 'dal', were suffering from lathyriasis.

The estimation of manganese in urine, blood, C.S.F. and faeces has revealed no useful information, and has not helped us to understand further the pathogenesis of the disease and the

distribution of the metal after absorption. The levels of the metal in the various fluids were comparable to those of controls unexposed to manganese (Tables XVII, XVIII, XIX & XX). Both groups showed similar amounts of excretion of manganese via urine and faeces that via faeces being far more than by urine. Again no difference was noticed between the workers from Mine No. 1 and Mine 9 although the former had been away from work and therefore from dust exposure for over 2 to 3 years, whilst the latter were still working till they were brought over to Bombay for the tests.

It was, however, noticed after administration orally of EDTA in patients that only the serum manganese rises (as much as threefold) the C.S.F., urine and faeces showing no appreciable change. In controls, oral administration of EDTA caused no rise in serum manganese. Again, intravenous EDTA by drip in two patients (No. 1 and 825) showed no rise in serum manganese although oral administration had done so. We have no explanation for this unusual occurrence.

Another finding is that C.S.F. manganese in 6 out of 8 patients is higher than serum. But in half the controls this is also true. The significance of this observation then remains doubtful.

One of the workers who was a driller in Mine No. (Case No. 20) was brought to Bombay straight from his duties, as a doubtful case of pre-manganism, the manganese content of his various body fluids show no difference from the established cases or the controls.

The literature on this subject is plentiful but conflicting (Penalver, 1955; Cotzias, 1958; Elkins, 1959) and no author has found that estimation of these fluids has given a clear guidance as to the physiopathology of this disease. The manganese levels in body fluids is also unhelpful in picking out the early or borderline cases of pre-manganism, so that early isolation of these cases cannot be made on biochemical grounds. We have found that there is no correlation between the level of the manganese in the various body fluids and severity of the disease or the amount of dust exposure.

Elkins (1959) mentions on insufficient evidence that "the concentration in the blood, while somewhat variable, is probably the best practical biological index of manganese exposure". In Cuban patients, the blood manganese concentrations ranged from 1 to 47 microgms per 100 gms blood but in all cases values above 7 microgms were obtained. The papers from Cuba by

Penalver, which we presume are mentioned here make no mention of control studies on normal subjects in that country, preferably living near the mine area and without local control estimations these readings lose their importance.

The haematological changes with manganese intoxication: There was no clinical evidence of any distinct haematological syndrome or disease as such. There were no cases of obvious polycythemia with plethora of the face, hypertension, occlusion or bleeding from blood vessels, enlarged spleen or liver. or the other multiple manifestations of well known polycythemia. What struck us most was that in the manganese mine, in workers of any category (not drillers only) the red blood cell count and the Hb % in gms. was on the higher side of normal or above normal. This was a little more so in the underground mines than in the open cast mines. As mentioned before, we selected a mine where manganism was most evident, and did a control survey of the population around. And again, what struck us (although a negative point) was the relative lack of anaemia, with normal estimates in the majority of individuals, and higher than normal in quite a few. In view of the low living standards, and also widespread helminthic infestations in the villages of India, these results become more significant. Under these circumstances, we feel that manganese may be playing some role in stimulating the haemopoitic system or helping absorption of iron in the gut. The absorbed iron is carried by the blood and deposited in the various reticuloendothelial tissues for further use in manufacture of haemoglobin and to act as iron store. The amount of serum iron depends largely on one factor only, *i.e.* the need of the body for iron as for example, after haemorrhage. But it also depends on how rapidly it is absorbed and that may depend to some extent on the manganese in the gut. Serum iron estimations in our first six patients from Mine No. 1 were considerably higher than normal, and in the absence of any evidence of a great need for the iron by the body, the high level may be a reflection of the role of manganese in absorption of iron.

Regarding the eosinophilia observed in the miners and the adjacent population, we are not certain if it is the manganese or the chronic helminthic infestations or some other cause operating in the villages.

Penalver mentions that with prolonged exposure to manganese dust increased haemoglobin % and mild polycythemia are noticed. He ascribes it to direct bone marrow stimulation by manganese, but gives no reason for it. Rodier mentions no such changes. Neither have discovered any eosinophilia. Whether

helminthic infestations near those mines in Cuba and Morocco existed or not is not mentioned.

Manganese Pneumopathy : In the literature there are several references to manganese and pulmonary complications. In 1921, Brezina pointed out the unusually high incidence of pneumonia in workers handling manganese ores. German authors (Heine, 1943; Baader, 1953) also pointed out the high morbidity and mortality amongst workers exposed to manganese. Rodier (1955) reports an incidence of 3.7% pneumonia and other respiratory diseases amongst manganese workers. He also mentions acute pneumonia leading to heart failure on the 5th and 10th days. We are of similar opinion that pulmonary complications such as tracheitis, bronchitis and pneumonitis are quite common amongst the manganese miners in India and are a direct hazard of the dust; 19% of workers gave a previous history of pneumonitis and 39% a history of bronchitis. X-Ray examination revealed no specific lung changes due to manganese. As we had very little opportunity to examine acute cases of pneumonitis, no X-Rays of this condition are available.

There were 10 cases of pneumoconiosis out of 243 workers radiologically examined (4.1 per cent). 20 cases out of these select cases showed radiological evidences of tuberculosis or pleurisy.

Manganese Intoxication and Environment

The extent of manganese poisoning will naturally depend on the concentration of manganese in the dust inhaled, and the period over which the workers are exposed to such dust. The workers in manganese mines are usually exposed to maximum manganese mine dust concentration in course of their actual work. The rest of the shift period they generally rest or are away from the working place. There is no scientifically established M.A.C. value for manganese dust, though according to the American authorities, it is arbitrarily set at 6 mg/M^3 of air for daily eight-hour exposure. But there are records of such higher concentration of manganese in air without any poisonous effects. Flinn et al (1940) have reported concentration of manganese as high as 173 mg/M/^{3}air. They did not find any poisoning cases among workers breathing air containing upto 30 mg of manganese/M^3 of air. The work of all investigators upto date including Flinn indicates that massive exposure is necessary for the development of manganism. It is also believed that newly drilled dusts are more poisonous than old dusts. According to Rodier (1955) braunite is more poisonous than pyrolusite. He feels that 'that less oxidised the compound, the higher its toxicity'.

In a survey conducted by the United States Public Health Service, no cases of manganese poisoning could be found among workers exposed to air containing less than 38 mg. of manganese per cubic meter of air (Patty 1949). Only one man showed some symptoms after 10 months of exposure to that concentration and another man in less than a year when exposed to 50 mg. of manganese per cubic metre of air. Patty also mentions chronic manganism in two of eleven men exposed to a concentration between 30—59 mg. per cubic metre and in eight of ten men exposed to 90 mg. of manganese per cubic metre of air.

Davies (1946) reported dust counts of 100—200 million particles per cubic foot of air of very fine dust and average manganese concentration of 210 mg. per cubic metre of air among British workers in a Potassium permanganate mill. He attributed high incidence of Pneumonia and Bronchitis in the workers to this manganese dust exposure.

If the data collected by this Committee and presented in Tables IV and V are considered in the light of the experience above, it is found that the concentration of dust in air in only a few underground mines (*e.g.* Nos. 1 and 5) may be taken as massive under dry drilling conditions. The obvious reduction in dustiness and dust hazard can also be seen clearly from the two Tables IV and V. It must be remembered in this connection that the data presented correspond to the condition of working as found during the short visits of the Committee and may not be sufficiently indicative of the average working atmosphere.

The Committee had visited all the underground manganese mines in India and a few surface ones too, but definite cases of manganese intoxication were encountered only in two mines, namely Mine No. 1 and Mine No. 9. The obvious doubt that arises in one's mind is whether these two mines and the workers in the two mines are in any way different from the rest. These two aspects are discussed separately below :

I. *Are these two mines different from others ?*

Both the Mines No. 1 and No. 9 are located in Madhya Pradesh. The main type of ore in both is predominantly Braunite and to a certain extent Psilomelane—a feature common to all other mines also. The available data on ore analysis from official and mine agencies do not lend to any clues. A detailed petrographic analysis of the ore samples from different mines visited, over and above the routine geological analysis, would have been helpful perhaps to give a clue to any specificity of factors resulting in manganese intoxication only in these two mines and not in other mines. But that was not possible.

Under these circumstances, it was considered necessary to go into the details of working of these two mines. Mine No. 1 was being worked for a number of years. The deposit is a reef of manganese ore extending from east to west over 500 to 600 metres approximately. The reef seems to be very thin in the east. The western half is about 90 metres wide. The whole of it is mined. The eastern one-third is all stopped. Perhaps there were three shafts in the closed area. Shafts 4 and 4A present now are the downcast ones separated by about 12 metres. It is reported that at one time they had a 30 H.P. fan to exhaust the air from the westernmost portion of the mine but recently a new shaft No. 5 has been in operation. This is located about 1/3rd distance of shaft No. 4 to the westernmost point. After the sinking of this shaft, the exhaust fan has been removed thus changing over again to natural ventilation. At the time of visit, the system was not at all satisfactory.

From records in the mine and enquiries from the miners, the following conclusions could be drawn. Since the very early years of development of this mine, pneumatic drilling was the practice. Invariably, they were drilling dry. Dry drilling even to this day is not prohibited by law in manganese mines but about a decade ago, the Chief Inspector of Mines recommended wet drilling. That the practice was in vogue corroborated by the statements of the drillers who have said that they were all drilling dry before the onset of the disease.

In Mine No. 9 they were initially doing only manual drilling. Subsequently, in this mine as also in all others being run by a corporate management, pneumatic drilling was introduced, with instructions to workers to use only wet methods. But from the company records it was clear to the Committee that some of the workers preferred to use the pneumatic drill dry, for reasons of convenience. Actually, convincing evidence of warning and punishment of defaulters was shown to the Committee by the management. Some of these defaulters were the same intoxication cases which were examined. An interesting feature was that the majority of the positive cases in Mine No. 9 belonged to one gang and they were all specifically employed at sinking a particular shaft in the mine and they perhaps developed the symptoms soon after. It is difficult for us, however, to elicit at this stage whether the particular operation or the ore composition was very different from the usual and, therefore, gave rise to the hazard not present with other workers working elsewhere in the mine.

Under similar circumstances, in both the mines, it may be reasonably concluded that the dry drilling operations were an important causative factor in manganese intoxication.

Dry drilling is known always to create a greater dust problem than wet drilling. Even our data corroborate the same. Figures as high as 362 mgm. per cubic metre of air were encountered by the Committee in the dry drilling operations in Mine No. 1. On the other hand, in the same mine, wet drilling gave a figure of less than one milligram per cubic metre of air. This indicates the very great scope for manganese dust to be inhaled by the miners while drilling dry. In other mines, the dry drilling figures were not as high as in Mine No. 1. The moisture content of the ore varies from mine to mine and the greater the moisture as perhaps in Mine No. 9, the lesser would be the dustiness (Table IV).

The marked difference in the possible dust exposure in both the mines is perhaps reflected in the relative incidence of intoxication too. In Mine No. 1 there were eleven severe to moderately severe cases and only four mild cases, whereas in Mine No. 9, there were only four severe cases but nine mild cases. The difference in severity of incidence is also statistically significant. (chi square value = 5.1964; significance at 5% level.)

A relevant question would be that if dry drilling was the practice in the early stages of all the manganese mines and if the manganese ore has about the same composition in all the mines, why is it that not even a single case of intoxication was encountered in the other mines, some of whom were following fairly standard mining practices?

There are three possible reasons :—

(a) The very high moisture content of the mine ores determines favourably the settling properties of the air-borne dusts. The dust counts were all taken as drilling was in progress and gives an indication only of the maximum degree of the hazard.

(b) In a majority of the other mines there were no pneumatic drills being used.

(c) Any manganese intoxication cases that were present in other mines were perhaps lost sight of. Some of the positive cases from Mine No. 9 were actually out of work and they had to be traced back to their village homes. If the Committee had visited the same mines No. 1 and No. 9, a year or two later, all the positive cases in this study would have been untraceable.

The first and the most important recommendation, therefore, of the Committee would be to ensure wet drilling methods and control of the air-borne dust underground.

II. *Are the workers who developed the manganese intoxication different from others?*

Individual susceptibility to any disease is difficult of definition, more so in such cases as those of manganese intoxication where the epidemiological variables are so many in number. For example, nearly all the mild cases from Mine No. 9 have had a manganese dust exposure of 10 or 15 years or even more, whereas in Mine No. 1, exposure to as short a period as 6 months lead to acute intoxication. As more severe cases were encountered in Mine No. 1, they were gone into greater detail.

The positive cases were living in the three labour camps—camps 1 and 4, owned by the management and camp 3 owned by the contractor. Of fourteen out of the fifteen cases considered positive by the Committee at the time of the visit, one was from camp 1, four from camp 3 and nine from camp 4. Each of these camps had an independent water supply—one or two dug wells. Except the South Indians who were running a cooperative mess, all the others were eating individually and had no common source of food, nor had they any uniform food habits. The staple food of the South Indians was mainly rice and that of the Maharashtrians 'javar' and maize. Majority had also supplements of wheat. Potato was perhaps the commonest vegetable used by all of them. The diet in all cases, and in fact of the community, was deficient qualitatively and ill-balanced.

All the fourteen cases were from different housing units. Two cases in camps 3 were from neighbouring units but they occurred nearly one year apart. There were three cases, however, in block (2), camp, 4 which were reported within a period of one year; two cases were neighbours and the third was two housing units distant. There seem to be, therefore, no predisposing factors of diet and infectivity in the aetiology of the intoxication.

Are people from any particular area more susceptible than others? In Mine No. 1, a break-up of the positive or near-positive cases of manganese poisoning was as follows :

7 per cent from the former Bombay State;
10 per cent from the South;
8 per cent from Uttar Pradesh; and
13 per cent from Madhya Pradesh.

The incidence of intoxication was maximum amongst the drillers. The majority of the drillers were from South India; two out of every three drillers or drillers' mates were from the South, mainly from the State of Kerala. Strangely, the incidence of poisoning cases amongst the South Indian drillers was the lowest. Only

14% of the drillers from the South showed any symptoms compared to 27% in Uttar Pradesh drillers, and 40% in Bombay and Madhya Pradesh men.

It may, therefore, be reasonably concluded that there is perhaps no racial susceptibility to this disease.

Working Environment :

Nearly all the manganese miners in India—the large majority of them are opencast mines and hardly a dozen are underground. Actually, they are not deep underground—the deepest being some 700 feet below the surface. At least for some years to come, the deepest mine is not likely to be very much deeper than 1,000 feet.

Natural ventilation systems cannot always be depended on for optimum working conditions and we found ventilation rather poor in all the mines. None of the mines used artificial ventilation.

There are two aspects of ventilation underground to be considered :

(*a*) To make the mine air safe for the underground workers to breathe;

(*b*) To make the working conditions physically comfortable.

A. *Safe Working Environment*

We have recommended elsewhere wet drilling to be made compulsory to minimise dustiness and the dust hazard.

Unfortunately, effect of ventilation on health was not given a serious consideration so far either by the Government or by the managements as far as metalliferous mines are concerned. As concentration of the dust in the general mine air is an important matter for consideration, the question of dust suppression should be borne in mine while ventilating the underground workings.

For creating an effective ventilation underground, there should be a proper "motive column" or the equivalent pressure producing ventilation, overcoming the mine resistance. This is the only solution irrespective of any consideration whether this is achieved by natural or artificial means. Ventilation standards have to be set, and if the set standards are not achieved by natural systems, artificial systems should be insisted on.

But we are not in a position to recommend any maximum permissible concentration of dust, just because implementation is impractical for various reasons and controversies at defining such ventilating standards are age-old. A maximum permissible concentration limit of 5 mgm./cubic metre may be tentatively taken as satisfactory.

B. *Comfortable Working Conditions*

Even in the best of naturally ventilated mines, the deadends do not receive any current of air which, unless the greatest care is taken, shortcircuits from a point further behind. In order to circulate effectively the air has to be carried to the face and we recommend that an air velocity of 50 feet per minute be achieved at points not farther than 5 feet from the face.

Artificial ventilation by mechanical means—by positive pressure is perhaps a very desirable solution but this requires more deliberate thinking, weighing the costs to industry and this Committee is not perhaps competent to pass a judgment. One other suggestion is worth mentioning *i.e.* periodic release of compressed air jet has never been considered as a mechanism for producing a continuous current, although it has been of assistance in clearing the gases and dusts, but this is likely to add to the comfort of the workers.

CONCLUSION

From the previous chapters one can make out that manganese intoxication has so far been a minor problem, minor in the sense that only some 28 cases were encountered in all the 12 mines visited. The problem thus is not of a serious nature not only because the number is so small but also because the cause and effect relationship is fairly clear in the minds of the Committee. If rigorous measures are adopted to prevent dry drilling underground, if proper ventilation is instituted and if cases are detected early and rehabilitated, there should be no cases of manganese intoxication in future.

CHAPTER VII

RECOMMENDATIONS

The Committee's recommendations are as follows :

(1) Dry drilling must be stopped at all costs and wet drilling introduced compulsorily both underground and at surface.

(2) In general, dust control methods are strongly recommended wherever a hazard exists.

(3) In underground mining practices, the following ventilation standards are tentatively recommended :

(a) Maximum permissible concentration of 6 mgm. of manganese dust per cubic metre of air.

(b) A minimum air velocity of 50 ft. per minute at the work faces and deadends at points not more than 5 feet away from the worker.

(c) As a check, periodic dust and ventilation surveys of the underground environment should be done.

(4) All manganese mines should have suitably qualified medical officers whole time or part time.

(5) All management personnel in the manganese mining should be conversant with the occupational risks in the industry.

(6) Periodical medical examination of all miners should be done and adequate records maintained.

(7) As soon as early diagnostic symptoms and signs are recognised, the worker should be withdrawn from his dusty environment to a suitable surface job and the proper authority notified.

(8) Treatment : The Committee feels that there is no specific remedy for the disease and the affected patients should be rehabilitated in new occupations suitable to their physical condition.

Treatment with Calcium EDTA was given to patients both orally and intravenously without any remarkable success. Parpanit given orally gave considerable symptomatic relief and made walking and movements easier. The beneficial effects of the treatment lasted only as long as the drug was given. Physiotherapy and occupational therapy were useful adjutants in the reha-

bilitation of these patients. Details of treatment attempted are given in case records.

(9) Manganese poisoning in the mining industry should be made a compensable disease under Schedule III of the Workmen's Compensation Act, relating the extent of compensation to the neurological damage.

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APPENDIX I

Case Histories of Chronic Manganese Intoxication Patients

Patient No. 1. *R.H.--Male* 24, (*mine No.* 1).

History : This patient had been working as a loader for 5 months and prior to that as a driller for 7 months. He had stopped working for 2 months when we examined him first on 15-9-1959. He noticed some loss of appetite as soon as he first started working in the mine. Six months ago, he felt weak and easily tired; he lost a little weight and suffered from occasional bouts of headaches. At this time, he found difficulty in going up and down the mine leading to numerous falls. Sitting, walking and standing became difficult. He had cramps in his lower limbs. He also gradually become impotent. About four months ago he himself noticed a tendency to excessive unprovoked laughter. At times, he would be very depressed and start weeping for no apparent reason. He maintained that his intellect and memory were not so accurate as they used to be and he was forced to give up work 2 months ago. There were no sensory symptoms.

Examinations : The patient was well built. There was a slight pallor of the mucous membranes. His mental state was normal. He had a fixed mask like face with a smiling expression. When stimulated to laughter, he found it difficult to stop. A mere smile or look provoked a prolonged crowing laughter. His gait showed typical propulsion with rolling from side to side, and there was marked retropulsion resulting in a fall when he walked backwards. There was minimal motor weakness in all four limbs and generalised slowness of movement. There was no ataxia, nor did he have any tremors. The sensory system was normal, the upper limb reflexes were brisk, the lower limb reflexes were exaggerated, the abdominal reflexes were present and the plantars were extensor. The other systems were normal and the blood pressure was 110/70 mm. He was examined in Bombay again, a year after the first examination, and the same physical signs were elicited. He had not improved, nor got worse.

Investigations

1. Blood	RBC	4·10 mill/ cmm.
	WBC	8,500/cmm. P 43, E 22, L 34, M 1.
	Hb	8·6 gms %
	PCV	33%
	VDRL & RMT	Negative
	MCV	80 c./u/u
	MCHC	26%
	Reticulocytes	1·8%
2. Fundi	Normal. No metallic ring seen on slit lamp examination.	
3. Urine	Albumen and sugar absent. Microscopic examination showed occasional pus cells and a few calcium oxalate crystals.	
4. Faeces	Ankylostoma duodenale ova seen.	
5. Sputum	No A.F.B. seen.	
6. I.Q. test	Normal.	
7. X-Rays	Chest	Normal.
	Skull	Normal.
	Lumbar spine	Normal.
8. Air Encephalography	Showed normal sized ventricles and no excessive subarachnoid air collection. There was no radiological evidence of cerebral atrophy.	
9. Liver function tests ..	Total protein	7·1 gms. %
	Albumen	4·4 gms.%
	Globulin	2·7 gms. %
	Alkaline phosphatase	8·7 K.A. Units.
	Thymol turbidity	2 units.
	Icteric index	5 units.
	Van den Bergh	Negative.
10. Serum Iron	190 microgm. %	
Serum Copper ..	89 microgm. %	
Serum Vit B-12 ..	90 microgm. %.	

11. Manganese estimations in the body fluids (in micrograms).

	Urine		Blood	CSF	Faeces
10. c.c.		24 hr. collection	5 mls.	5 mls.	1 gm. (wet)
26-5-60	1·05	128·10 (1220 mls. total).	0·86	0·75	41·00
	After EDTA orally given 5 gms. daily from 12-6-60 *to* 21-6-60				
21-6-60	0·80	—	1·14	0·65	17·2
4-7-60	0·95	113·3 (1193 mls. total).	—	—	16·00
19-8-60			*Before EDTA* 2·10 *EDTA given i.v. 2·5 gms. in 500 cc. saline for 3 days.*		
23-8-60			1·08 *EDTA given for 6 days.*		
25-8-60			0·95 10 days after EDTA stopped.		
6-9-60			1·49		

12. Cerebro-spinal fluid	The CSF pressure was normal.	
	Proteins	30 mg. %.
	Globulins	Not increased.
	Sugar	62 mgm. %.
	Chlorides	710 mg. %.
	Cells	2 lymphocytes.
	W.R.	Negative.
	Lange's curve	0000000000
13. Bone marrow examination	The marrow is cellular. M:E: :2:1 Myeloid series shows normal differentiation. Eosinophils are in the upper limit of normal. Plasma cells are within normal limits. Erythroid series is normoblastic. Megakaryocytes are present and active.	
14. E.E.G. report	Well modulated 10 c.p.s. alpha activity at 15—30 microvolts. Short runs of 6 c.p.s. waves mostly in the central region but also noticed elsewhere including the posterior temporal areas. The patient could not cooperate for over-breathing or photic stimulation because of laughter.	

Treatment and Progress : He was given Calcium EDTA orally, 5 gms. in two divided doses daily for 10 days. Three days of observation brought no subjective or objective improvement. After that, he was given Parpanit (Geigy) (Diethylaminoetheyl-l-phenylcyclopentane-l-carboxylate-hydrochloride) 6.25 mgm. TDS orally daily increasing by one tablet, till he received 50 mgm. TDS and then the tablets were stopped. The improvement was obvious. His gait became steady, there were no falls and very little lurching from side to side, or propulsion. Retropulsion had disappeared, and he could squat without falling backwards. A backward push caused no fall as previously. The speech was more distinct, but the mask-like face and abnormal laughter persisted. The improvement sustained for 10 days and then gradually disappeared over another three weeks. We felt Parpanit was the useful agent (by diminishing body tone) and not Calcium EDTA. To make certain after 2 months drug free interval, Calcium EDTA was given by intravenous drip 2.5 gms. in 500 ccs. of saline daily for six days. This time the patient was observed for full 20 days and no improvement of any kind was noticed. He was then put on Parpanit (6.25 mgm. tablet)—one tablet TDS increasing daily by one tablet TDS till 50 mgm. TDS was reached. By the time he reached that dose there was again considerable ease in walking, standing, squatting and turning. His speech was a little more distinct. The mask-like face and the laughter persisted. As Parpanit seems to symptomatically improve the patient, whilst he is on that drug, he was advised to continue the drug on the same dose on discharge. However, he had the side reactions of the drug and was not happy to continue to take it.

Patient No. 2. *O.M. male,* 20 (*mine No.* 1).

History : The patient started work as a loader in 1956 and continued till 1958. His symptoms developed at the end of 1958 and he left work within a month. He was examined on 15-9-1959. He first found that he was not able to speak clearly and his voice was getting less distinct and softer. He could not walk properly, and showed a tendency to run in stead, and swing from side to side. He had several falls. He also complained of being easily fatigued, of loss of appetite, body pains, daily headaches and at times irritability. The symptoms developed rapidly for the first month after the onset but once he left work he worsened only a little.

He was mentally normal. His face was mask-like but not severely so. He laughed excessively. His laughter was most striking and out of all proportions to his other symptoms and signs which were very mild. His speech was indistinct and

monotonous but louder than his colleagues. There was excessive dribbling of saliva. There was generalised asthenic-weakness of all four limbs with normal tone. His coordination was good, but slow; so were the alternating movements. His gait was staggering with propulsion and marked retropulsion. He did not walk on his toes (cock-walk) like the others. The Romberg test was negative, but when pushed, he fell backwards easily. The sensory system and deep reflexes were normal. The plantars were flexor.

Investigations

1. Blood	RBC	4·5 mill/cmm.
	Hb	14 gms. %.
	WBC	8,800 /cmm. P55, L23, E 20, M2
	PCV	41%.
	ESR	10 mm/hr.
	VDRL & RMT	Negative.
	MCV	90 c/u/u.
	MCHC	34%.
	Reticulocytes	1%.
2. Faeces	No ova or cysts seen.	
3. Sputum	No A.F.B. detected.	
4. I. Q.	Normal.	
5. Liver function tests :	Total protein	7·4 gms. %.
	Albumen	4·1 gms. %.
	Globulin	3·3 gms. %.
	Alkaline phosphatase	8·4 K.A. units.
	Thymol turbidity	1 unit.
	Icteric index	3 units.
	Van den Bergh	Negative.
6. Cerebrospinal fluid	Manometry	Not done.
	Proteins	30 mgm. %.
	Globulins	Not increased.
	Sugar	58 mgm. %.
	Chlorides	700 mgm. %.
	Cells	4 lympho/cmm.
	W.R.	Negative.
	Lange's curve	0000000000
7. Urine	Normal.	
8. X-Rays of Chest, skull and lumbar spine were normal.		
9. Serum Iron	285 microgram % and 260 microgram % (on two different days but on similar diet).	
Serum copper	83·33 microgram %.	
Serum Vit. B_{12}	88 micromicrogram %.	

10. Air encephalogram showed normal ventricles and no evidence of cerebral atrophy.

11. Bone marrow .. Marrow is cellular. M : E :: 2·5:1. Myeloid series shows normal differentiation. Eosinophils are slightly above normal. Plasma cells are normal. Erythroid series is normoblastic. Megakaryocytes are present and active.

12. Estimation of Maganese in Body Fluids (in Micrograms) :

Urine		Blood	CSF	Faeces
10 mls.	24 hrs. collection	5 mls.	5 ml.s	1 gm. (wet).
0·50 (27-10-59)	—			
0·62 (30-10-59)	...	0·46	1·32	17·7 (23-11-59)
0·39 (16-11-59)	46·6 (Total urine 1200 mls.).	(3-12-59)	(3-12-59)	15·0 (4-12-59)
Immediately after EDTA orally 500 mgm. TDS for 7 days.		3 days after EDTA		
0·85 (19-12-59)				
0·70 (21-12-59)		1·25 (21-12-59)		

13. Opthalmic examination revealed no corneal ring.

14. EEG report .. .. The EEG is abnormal. Well modulated 10 c.p.s. alpha activity of normal voltage is seen specially in the parietal and occipital areas. The striking abnormality is of runs of 6-7 c.p.s. waves at 50 to 60 microvolts. These are seen throughout the 40 minute record. These are also noticed in sleep and the longest run lasts for 19 seconds. The bursts recur every 4 to 20 seconds. The humps are well formed in sleep. During hyperventilation and photic stimulation the runs continue, otherwise no fresh abnormality evoked.

15. Blood estimations .. Alpha ketoglutarate .. .. 0·30 mgm. %
pyruvate .. .. .. 1·31 mgm. %
lactate .. .. .. 7·34 mgm. %.
Copper oxidase .. .. .. 0·14 (Extinction coefficient).

Treatment and progress :

Whilst in the hospital, even without treatment his gait became more steady and his speech more distinct. He was given Calcium EDTA orally for 7 days—500 mgm. capsules, one capsule three times a day, and Parpanit 6.25 mgm. tablets, one tablet QDS and later 2 tablets QDS. The patient took the latter for about 15 days and then stopped although instructed to take larger doses for three months. No remarkable improvement was seen after therapy.

Patient No. 3. *C.G. male.* 30 (*mine No.* 1)

Date of examination : 15/9/1959.

History : This patient started working in 1951 as driller and continued upto 1956. He left the work in 1957, six months after the onset of the symptoms. The patient was perfectly all right upto 3 years ago when he developed generalised weakness, with a tendency to be easily fatigued, accompanied by anorexia and difficulty in speaking clearly and loudly. There was considerable emotional instability with excessive laughter. He also noticed that his gait had changed and he could not check himself from falling. He had occasional headaches, felt drowsy at all hours and thought his memory and intellect had deteriorated. He had some difficulty in balancing himself. The symptoms progressed for 6 months or so, and then became static after he left work in the mine. He has had an occasional cough but no haemoptysis.

Examination : His mental functions were good. He had an emotionless face, with an occasional tendency to grin spontaneously and without reason; but there was no pathological laughter. He talked with a low, monotonous, indistinct voice. There was a slight tremor of the protruded tongue. He had a slight weakness of all the four limbs. Coordination and alternating movements were good but slow. The tone was normal in the upper limbs but definitely increased in the lower limbs, specially at the ankles. The sensory system was normal. The upper limb deep reflexes were normal but those of the lower limbs were brisk. The abdominal and cremasteric reflexes were present. The plantar responses were flexors. The patient walked with a quick propulsive gait, mostly on his toes. There was marked retropulsion. The Romberg test was negative with the eyes open, but with the eyes shut there was a tendency to fall back. On the slightest push backwards he tended to fall down. The blood pressure was 130/80 m.m. Systemic examination was normal except for a slight pallor and minimal clubbing of the finger nails.

Investigations :

1. Blood	RBC	5·2 mill/ cmm.
	Hb	14·6 gms.%.
	WBC	4,900 /cmm· P 70, E 8, L 19, M 3.
	PCV	42%.
	ESR	4 mm/ hr·
	MCV	80 c/u/u.
	MCHC	34%.
	Reticulocytes	1%.
2. Blood VDRL and RMT was negative.		
3. Urine	No albumen and sugar detected. Microscopic examination was normal.	
4. Faeces	Ova of ankylostoma duodenale and cysts of Entamoeba Histolytica seen.	
5. X-Rays of skull, chest and lumbar spine were normal.		
6. Sputum	No A.F.B. detected.	
7. I.Q. test : Normal.		
8. Liver function tests ..	Total proteins	5·8 gms. %.
	Albumen	2·8 gms. %.
	Globulin	3 gms. %.
	Alkaline phosphatase	6·6 K.A. units.
	Thymol turbidity	2 units.
	Icteric index	5 units.
	Van den Berg	Negative.
9. Cerebrospinal fluid ..	The initial pressure and manometry were normal.	
	Proteins	60 mgm. %.
	Globulins	Not increased.
	Sugar	56 mgm.
	Chlorides	680 mgm.%.
	Cells	3 lymphocytes.
	W.R.	Negative.
	Lange's curve	0000000000
10. Serum Iron	145 microgram % (16-10-59) and 105 microgram % (11-11-59).	
Serum Vit B_{12} ..	55 micromicrogram %.	

11. Estimation of Manganese in Body Fluids (in micrograms).

Urine		Blood	CSF	Faeces
10 mls.	24 hrs. collection	5 mls.	5 mls.	1 gm. (wet).
1·57 (27-10-59)				
1·34 (30-10-59)				
0·58 (16-11-59)	124·50 (Total urine 2,400 mls.).	1·75 (28-11-59)	Not done	18·90 (23-11-59)

12. Fundi : Normal — No corneal ring detected.

13. EEG report .. .. The EEG was completely normal with well modulated 9—10 c.p.s. alpha activity spreading upto the frontal areas. During sleep the humps were badly formed as in some other cases.

14. Quantitative Blood examination:—

(1) Alpha ketoglutarate ..	0·34 mgm. %.
(2) Pyruvate	1·38 mgm. %.
(3) Lactate	7·45 mgm. %.
(4) Copper oxidase	0·28 (Extinction coefficient).

The patient did not wish to stay for a further period in the hospital for treatment.

Patient No. 4. N.G. *male*, 27, (*mine No.* 1).

Examined on 1/10/59.

History : The patient started work in 1956 as a driller and worked upto 1958. He left the mines in the beginning of 1959 within a month of the onset of the symptoms. The patient was completely all right till 10 months ago when he gradually found that he could not speak loudly. The words became indistinct and at the same time his gait became peculiar. He was unable to walk slowly and there was a tendency to run instead of walking. He found balancing difficult and had several falls specially on being pushed even slightly. More recently, he had noticed a slight tremor of the right arm and that the right hand was becoming flexed at all the joints, giving him considerable pain and difficulty in opening it. The initial deterioration was for three months but since then the condition had remained static except for the right hand which had worsened.

Examination : He had a mask-like, emotionless face and, like the others, he looked like an idiot, but actually was quite intelligent. He grinned all the time and occasionally burst out into a loud crowing uncontrollable laughter ending in a tremendously high pitched noise. The laughter was both spontaneous and evoked by a smile or a question. His speech was low, indistinct and monotonous, and he could not raise his voice. He had a generalised asthenic weakness of all the four limbs, of a mild degree, the right upper limb was however the weakest, and the fingers of the right hand were strongly abducted and flexed, somewhat in the position of a carpopedal spasm. It was difficult to open the hand forcibly. The tone was moderately increased in the lower limbs, but not in the upper ones. There were no tremors, and coordination was good but slow. The gait was a typical cock-walk with a tendency to run; retropulsion was marked and he easily fell backwards on being pushed slightly. The deep reflexes were normal in the upper limbs, brisk in the lower limbs; the abdominals were present and the plantars were flexor. The other systems were normal; and the blood pressure was 116/78.

Investigations :

1. Blood	RBC	4·3 mill/cmm.
	Hb	13 gms. %
	WBC	6,700 /cmm. P 69, E 12, L 15, M 4.
	PCV	40%
	ESR	45 mm/hr.
	VDRL & RMT	Negative.
	MCV	93 c/u/u
	MCHC	30%
	Reticulocytes	1·6%
2. Urine	Albumen and sugar were absent. Microscopic examination was normal.	
3. Faeces	No ova or cysts seen.	
4. Sputum	A.F.B. not seen.	
5. X-Rays	Chest, skull and lumbar spine were normal.	
6. Cerebrospinal fluid	The initial pressure was 90 mm. The standard manometric examination was normal.	
	Proteins	35 mg. %.
	Globulins	Not increased.
	Sugar	54 mgm. %.
	Chlorides	700 mgm. %.
	Cells	8 lymphocyte
	W.R.	Negative.
	Lange's Curve	0000000000

7. Liver function tests ..	Total proteins	7·7 gms. %
	Albumen	4·7 gms. %
	Globulin	3·0 gms. %
	Alkaline phosphatase	5·8 K. A. units.
	Thymol turbidity	1 unit.
	Icteric index	1 unit.
	Van den Bergh	Negative.
8. I. Q. test	Normal.	
9. Bone marrow ..	Marrow is hypercellular. M: E:: 1.5:1 Myeloid series shows normal differentiation· Eosinophils upper limit of normal to slight increase. Plasma cells within normal limits. Erythroid series is normoblastic. Megakaryocytes are present in fair numbers.	
10. Serum Iron	240 microgm, and 160 microgm. % (on two different days on routine diet, same on both days).	
Serum Copper ..	19·84 microgm. %.	
Serum Vit B_{12} ..	80 micromicrogm. per c.c.	

11. Manganese Estimation in Body fluids (in micrograms) :

Urine		Blood	CSF	Faeces
10 c.c.	24 hrs. collection	5 mls.	5 mls.	1 gm. (wet)
1·18 (27-10-59)				
3·92 (30-10-59)				
2·24 (16-11-59)	199 (Total urine 960 mls.).	0·50 (4-12-59) Immediately after EDTA, 500 mgm. TDS for 7 days. 2·40 (21-12-59)	1·15 (3-12-59)	16·8 (23-11-59) 15·2 (4-12-59)

12. EEG report	The salient features were : (1) Marked poorly modulated low voltage alpha activity throughout the record. (2) Inter-aereal difference poor. (3) Badly modulated humps in sleep. (4) Short runs of 4 to 6 c.p.s. waves of 40 to 50 microvolts seen during natural sleep.
13. Fundi Normal ..	No abnormal corneal rings seen on slit lamp examination.

14. Estimation of blood levels of.

(*a*) Alpha ketoglutarate ..	0·40 mgm. %.
(*b*) Pyruvate	1·34 mgm. %.
(*c*) Lactate	6·52 mgm. %.
(*d*) Copper oxidase	0·12 (extinction coefficient).

Treatment and Progress : Calcium EDTA was given orally 500 mgm. TDS for 7 days, along with Parpanit 6.25 mgm. four times a day. No improvement was noticed immediately. The patient was instructed to continue Parpanit in increasing doses upto 16 tablets in a day and then report for re-examination. The patient did not take treatment or report back.

Patient No. 5. *T.R. male,* 27 (*mine No.* 1).

Examined on 1/10/1959.

History : The patient started work as a driller in 1952 and left the mine in the middle of 1958, within a month of the development of his symptoms. He was completely all right till 2½ years ago. It was noticed that he was staring at people and had developed a peculiar face. After that he became irritable, and easily angered without any cause. He then developed weakness of the arms followed by weakness of the legs. The weakness, he thinks, has gradually increased to date. He also experienced considerable pain in the backs of the joints of the extremities. Six months after the onset, he found that his balance and gait were increasingly becoming poor and he had a tendency to fall. About 2 years ago his voice became softer and his speech indistinct. He also developed muscle cramps specially at night. He feels drowsy all the time and sleeps nearly 16 hours a day. He has recently developed some cough with pain in the chest and also breathlessness on exertion. He has lost 15 lbs. weight in 2½ years. The symptoms progressed for the first five to seven months and then his condition became static.

Examination : He had a non-blinking, mask-like face; a low, hardly audible, monotonous speech; and he could not raise his voice. His mental state was perfectly normal. There was generalised mild asthenic weakness of all the four limbs with normal tone and good but slow coordination. The patient had a tick in which he continuously flicked the fingers and the thumb. He walked with a wide based gait with a tendency to lurch from side to side. Retropulsion was marked. The Romberg test was

negative. The sensory system was normal; the reflexes were normal; abdominals were present; and plantars were flexor. The blood pressure was 105/70. Lumbar spine examination showed generalised stiffness in all movements.

Investigations:

1. Blood	RBC	5·5 mill/cmm.
	Hb	16 gms. %
	WBC	11,000 /cmm P 64, E 14, L 18, M4%
	PCV	41%
	ESR	10 mm/hr.
	VDRL& RMT	Negative.
	MCV	90 c/u/u.
	MCHC	32%.
	Reticulocytes	0·9%.
2. Urine	Albumen and sugar absent. Microscopically normal.	
3. Faeces	No ova or cysts seen.	
4. Sputum	Negative for A.F.B.	
5. Gastric analysis	Normal. No hyperacidity.	
6. Liver function tests	Total proteins	6·9 gms. %
	Albumen	4 gms. %
	Globulin	2·9 gms. %
	Alkaline phosphatase	6·4 K.A. units.
	Thymol turbidity	2 units.
	Icteric index	3 units.
	Van den Berg	Negative.
7. Cerebrospinal fluid	Initial pressure was 130 mm. of CSF. Jugular pressure and manometry were normal.	
	Proteins	25 mg. %
	Globulins	Not increased.
	Sugar	58 mg. %
	Chlorides	700 mgm.%
	Cells	6 lymphocytes.
	W.R.	Negative.
	Lange's curve	0000000000
8. I. Q. test	Normal.	
9. X-Rays of the chest, skull and lumbar spine were normal.		
10. Serum Iron	175 and 200 microgm.% (two separate readings) at an interval of 20 days, but on a similar diets)	
Serum Copper	89·28 microgm. %	
Serum Vit B 12	60 microgm. per c.c.	

11. Manganese estimation in Body fluids (in micrograms) :

Urine		Blood Serum	CSF	Faeces
10 c.c.	24 hrs. Collection	5 mls.	5 mls.	1 gm. (wet)
0·67 (27-10-59)				
0·90 (30-10-59)				
0·90 (16-11-59)	95 (Total urine 1140 ml.).	1·00 (4-12-59)	3·10 (7-12-59)	17·25 (23-11-59) 9·70 (4-12-59)
	Immediately after Cal. EDTA administered orally 500 mgm TDS for 7 days.	After EDTA		After EDTA
1·00 (19-12-59)				
0·60 (21-12-59)		2·50 (21-12-59)		14·7 (21-12-59)

12. Bone Marrow .. Marrow is cellular. M:E:: 2:1. Myeloid shows normal differentiation. Eosinophils slightly increased. Plasma cells are within normal limits. Erythroid series is normoblastic. Megakaryocytes are present in adequate numbers and are active.

13. EEG Report .. .. The salient features were : (1) well modulated normal alpha activity. (2) 6-7 c.p.s. runs of 40—60 microvolts lasting from 2—6 seconds, not involving posterior temporal leads. (3) Badly modulated low voltage humps in sleep.

14. Fundi .. .. .. Normal. No abnormal corneal ring noted on slit lamp examination.

15. Blood levels of .. (*a*) Alpha ketoglutarate .. .. 0·23 mgm.%
(*b*) Pyruvate .. .. .. 1·47 mgm.%
(*c*) Lactate .. .. .. 6·27 mgm.%.
(**0**) Copper oxide .. .. .. 0·17 (extinction coefficient).

Treatment and Progress : Calcium EDTA 500 mgm. TDS orally for 7 days, along with Parpanit 6.25 mgm. QDS. The patient was instructed to continue the latter at home for another three months and report regularly for follow-up. He discontinued treatment and failed to report but his companion says that he mentioned no improvement. When examined immediately after the above drugs on the day of discharge, there was no appreciable change for the better.

Patient No. 6. *A.K. male,* 27 (*mine No.* 1).

Examined on 1/10/59.

History : The patient started working in 1955-56 as a driller in the mines and left working in 1957 within a week of the onset of his neurological symptoms. He was completely all right till 2½ years ago when he noticed difficulty in speaking loudly and distinctly. This was followed by repeated falls and difficulty in walking. He also noticed that it was easier to run than to walk and if pushed backward, he fell down easily. The general body balance has been poor and over the last six months he has complained of occasional headaches not accompanied by vomiting. He has felt generally run down and tired with a weakness of the whole body but there is no actual paralysis. The initial deterioration of the condition was for 4-5 months and then the symptoms became static except for the speech difficulty which he thinks has been increasing to date.

Examination : It was found that the mental state was perfectly normal; in fact, on the sharper side for one coming from his strata of life. He had a slightly mask-like face. His speech was low, indistinct and monotonous. He could not shout. There was excessive, repeated, spontaneous and evoked laughter with a happy mood all the time. There was a slight asthenic weakness of all the limbs and the tone was increased in the lower limbs : coordination was good but slow. On walking, he rose up on to his toes and walked leaning forwards with a tendency to run. Retropulsion was marked. The Romberg test was negative, but when pushed backward, he fell. The deep reflexes were brisk all over, the abdominals were present and plantars were bilateral extensors. The other systems were normal and his blood pressure was 100/70.

Investigations :

1. Blood	RBC	5·3 mill/cmm.
	Hb	15·6 gms. %
	WBC	14,900/cmm. P 53, E 31, L 3, M 3.
	PCV	49%
	ESR	9 mm/hr.
	VDRL & RMT	Negative.
	MCV	92 c/u/u.
	MCHC	31%
	Reticulocytes	0·3%
2. Urine	Albumen and sugar absent. Microscopically normal.	
3. Faeces	No ova or cysts seen.	
4. Sputum	No A.F.B. seen .	

5. Liver function tests ..	Total proteins	7·3 gms. %
	Albumen	4·2 gms. %
	Globulin	3·1 gms. %
	Alkaline phosphatase	5·8 K.A. units.
	Thymol turbidity	3 units.
	Icteric Index	1 unit.
	Van den Bergh	Negative.
6. Cerebrospinal fluid ..	Proteins	20 mgm. %
	Globulins	Not increased.
	Sugar	57 mgm. %
	Chlorides	720 mgm. %
	Cells	3 lymphocytes.
	W.R.	Negative.
	Lange's curve	0000000000

7. I. Q. Tests: Normal.
8. X-Rays of chest, skull and lumbar spine are normal.
9. Air encephalogram : Showed no cortical atrophy and was perfectly normal.
10. Bone marrow .. Marrow preparation is rather dilute. M:E::2:1. Myeloid shows normal differentiation. Eosinophils are in the upper limit of normal. Erythroid series is normoblastic. Megakaryocytes are present and active. A few present because of the dilute preparation.
11. Serum Iron .. .. 220 and 300 microgm. % (two separate readings with an interval of 20 days).

Serum Copper : 18.11 microgm.%

Serum Vit. B 12 .. 150 micromicrogm. per c.c.

12. Manganese estimations in body fluids (in micrograms).

Urine		Blood serum	CSF	Faeces
10 mls.	24 hrs. collection	5 mls.	5 mls.	1 gm. (wet)
1st admission		1·25 (4-12-59)		17·2 (23-11-59)
3·69 (27-10-59)				16·0 (4-12-59)
3·24 (30-10-59)				
0·95 (16-11-59)	105·5 (Total urine 1290 mls.).	After CAEDTA 500 mgm. TDS for 7 days (immediately after) 3·25 (21-12-59)	0·17 in 2 mls. (4-12-59)	After CAEDTA 500 mgm. TDS for 7 days.
2nd admission				
0·80 (26-5-60)	70·80 (total urine 850 mls.).	0·85 (26-5-60)	In 5 mls. 1·75 (26-5-60)	26·14 (26-5-60)
After CAEDTA 5 gms. daily for 10 days 0·90 (21-6-60).		After CAEDTA 5 gms. daily for 10 days 3·40 (21-6-60) (immediately	After CAEDTA In 5 mls. 1·10 (21-6-60)	After CAEDTA 34·60 (21-6-60) 26-36 (4-7-60)
1·15 (4-7-60)	124 (total urine 1079 mls.).	0.75 (13-8-60)		

13. EEG report	Well modulated alpha activity at 10 to 11 c.p.s. at 20 to 50 microvolts, during awake recording, otherwise no specific changes. During natural sleep, all the normal phases of sleep recording seen, except that the humps were badly formed and of low voltage.	
14. Blood levels of ..	(*a*) Alpha ketoglutarate	.. 0·54 mgm.%
	(*b*) Pyruvate	.. 1·36 mgm. %
	(*c*) Lactate	.. 5·47 mgm. %
	(*c*) Copper oxidase ..	.. 0·14 (extinction coefficient) (Ravino)

15. Eye examination by slit lamp showed no evidence of any abnormal corneal ring.

Treatment and Progress : On first admission he was given Calcium EDTA orally—500 mgm. TDS for 7 days, along with Parpanit 6.25 mgm., one tablet four times a day and instructed to take the latter in increasing doses upto 16 tablets in a day, if beneficial. The patient could not be persuaded to stay on for observation and did not take treatment as advised. He had made no improvement at the time of discharge, *i.e.* three days after stopping EDTA and on the seventh day of taking Parpanit.

On the second admission some months later, he was given 5 gms. Calcium EDTA orally in two divided doses for 10 days—he was observed for 3 days and no improvement noticed; then he was given Parpanit 6.25 mgm. TDS (orally) daily and increased by one tablet TDS to 50 mgm. TDS. When that dose was reached it was stopped. The patient experienced some side effects of Parpanit, but felt he walked better. On examination, the tone at the ankles had diminished. The cock-walk had disappeared. He did not fall backward when pushed. There was no retropulsion. Though his laughter had not changed, his speech was louder and more distinct. This improvement has been maintained though gradually getting less over three weeks. It was uncertain if EDTA or Parpanit had the good effect—so after a drug-free nine weeks' period, when he was almost back to the pre-treatment level, Parpanit was started again in the same dosage schedule and again by the time 50 mgm. TDS was being administered there was considerable improvement in his speech and gait, but the abnormal face and pathological laughter persisted. He was advised to continue therapy.

This patient has been observed over nearly four to five years now and without doubt there is a definite but slow improvement in his condition since he left the mine 4 years ago. His laughter is not as hilarious as before, his speech is more distinct and even before Parpanit was given his gait was getting steadier over the years. However, the improvement cannot be called dramatic.

Patient No. 9. *J.S.—male,* 37 (*mine No.* 1).

Examined on 15/7/1959.

History : The patient worked as a driller for a year and a half, doing mostly dry drilling. The history of his illness starts two years ago when he developed asthenia, insomnia, a tendency to excessive weeping and about a year ago, impotency and inarticulate speech. Also at the onset of the illness, he found difficulty in going downhill and into the mine. He had several falls whilst walking. Gradually this weakness increased and he has now become slow in all his movements.

Examination : He was very slow, apathetic and looked depressed. Left alone, he would make no effort to walk. He had an emotionless face, and there was dribbling of saliva. His speech was very soft, monotonous and difficult to understand. His intelligence was normal but his concentration was poor. His gait was slow and shuffling and there was no retropulsion. There was asthenic weakness of all four limbs with exaggerated lower limb reflexes. The abdominals were present and the plantars were flexor. The blood pressure was 100/70. The white blood cell count was not done but the differential count showed an eosinophilia of 25 per cent. The Hb per cent was 7.25 gms. X-Ray of the chest was normal.

Patient No. 10 *R.M.—male,* 27, (*mine No.* 1).

Examined on 15/7/1959.

History : The patient worked as a loader for 1½ years and then as a driller for 1½ years. He has been off work for 3 years. He developed gradual weakness of the limbs about six months before leaving work. He found considerable difficulty in going up and down the mines. He found difficulty in turning and he fell easily specially on walking backwards. He has felt generally tired, run down and has developed an excessive desire to sleep for the last 2 years. At times he has had a tendency for uncontrolled laughter.

Examination : The pathological laughter was quite remarkable. He had a festinant propulsive gait. There was also a tendency to retropulsion. On trying to squat he would fall backwards. The speech was low, monotonous and indistinct. There was slightly diminished power of the four limbs but the tone was normal. There were no tremors; the tendon reflexes were brisk and equal; the plantars were equivocal; the abdominals were present.

The blood pressure was 125/80 and general examination revealed a slight pallor. The differential count showed an eosinophilia of 15 per cent and the Hb per cent was 16 gms. His chest X-Ray was normal.

Patient No. 11. *R.H.—male,* 25 (*mine No.* 1).

Examined on 15/7/1959.

History : The patient bored holes on the surface of the mine for a year, then worked on the water pump for 6 months, and for the last 2 years he has been dry drilling, underground, for a year and a year on the surface. He left work in November 1955.

The symptoms started 3 years prior to leaving the mines, gradually increasing in severity till he left work, since when the condition has remained static. He complains of weakness, loss of appetite, a tendency to be easily fatigued, excitability, impotence, lack of tolerance, irritability and occasional bouts of weeping. He also has difficulty in climbing up and down the stairs and in walking. There is no history of pathological laughter.

Examination : He seemed quite cheerful and there were attacks of spasmodic laughter. His face was fixed and expressionless. The gait was markedly spastic with some amount of propulsion and considerable retropulsion. The speech was low, monotonous and indistinguishable. There were slight tremors of the tongue on protruding it. There was mild asthenic weakness of all four limbs with normal tone and no tremors. The sensations were normal; the tendon reflexes were all present and equal. The abdominal reflexes were present and the plantars were extensor.

The blood pressure was 124/84. There was a certain amount of pallor of the mucous membranes, otherwise the general examination was normal. The white blood cell count showed an cosinophilia of 16 per cent. The Hb per cent was 14.5 gms.

Patient No. 13. *G.I.—male,* 26 (*mine No.* 1).

Examined on 15/7/1959.

History : This patient had worked as a loader for a month and as a dry driller for about three years when his first symptoms developed. He left work within a month after that. His condition deteriorated for a year or so and then remained static to the time of our examination, when he had been off work for at least 3 to 4 years. His complaint started with tremors in his hands and later, difficulty in walking, sitting and standing. Six

months after the onset, he had difficulty in speech, and he could hardly be heard due to his very low voice. There was also excessive salivation. He had a tendency to increased sleep and has often had spasmodic laughter. He had difficulty in climbing up and down the mines and considerable body fatigue.

Examination: He had a mask-like face with intermittent grinning but no loud laughter. His speech was low, indecipherable and monotonous. The gait was of a spastic character with slight propulsion and marked retropulsion. His intelligence was average. The motor system showed lack of power due to asthenic weakness of the limbs. There was a moderate tremor of the outstretched hands; greater in the left than in the right. The tone was normal. There was generalised slowing of all movements. The deep reflexes were normal, the abdominals were present, the plantars were flexors. The sensory system was normal. The differential count showed an eosinophilia of 11 per cent. The Hb per cent was 15 gms. The chest X-Ray was within normal limits.

Patient No. 14. *R.T.—male,* 30 (*mine No.* 1).

Examined on 15/7/1959.

The patient worked as a loader for 1½ years, as a timber man for 2 years and then as a driller for 11 months. He left work soon after the onset of his complaints and has been off work for 3 years.

Three years prior to examination, he complained of weakness in the whole body but more so in the legs, with a tendency to fall down whenever he was carrying any machinery. The difficulty in walking has steadily increased to date. He tends to fall backwards easily. Over the same period of time, he had anorexia, impotence, excessive weeping, somnolence, lack of concentration and difficulty in speech.

On examination he had a depressed, expressionless face with a slight tendency to weeping. The gait was shuffling with a wide base and a tendency to lurch from side to side, and was definitely spastic. There was mild propulsion but marked retropulsion. He evinced great difficulty in walking on a straight line, and there was a tendency to fall. His intelligence was normal. The voice was low and monotonous but could be easily understood. The power in all four limbs was slightly diminished; and there was a fine tremor of the outstretched hands. The deep reflexes were normal, the abdominals were present and the plantars were flexors. There was diminished perception to pinprick up to the waist but there was not enough cooperation to

be certain about it. The general examination was normal except for a slight emphysema. There was slight pallor of the mucosa. The blood pressure was 140/80. The blood count showed an eosinophilia of 37 per cent and the Hb per cent was 13 gms. The chest X-Ray was normal.

Patient No. 15. *T.N.—male,* 30 (*mine No.* 1).

Examined on 15/7/1959.

History: The patient was a loader for the first three years and a dry driller for the last two years. The history started with asthenia and generalised weakness which was followed by tremulousness of the hands and feet. This was followed by difficulty in walking, with numerous falls. There was difficulty in getting up from a chair. Subsequently, he developed spasmodic laughter. This condition has remained stationary over the last two years. He has been out of the mines for at least three years. now. There has been definite disturbance of speech but it cannot be ascertained when it started. He also complains of insomnia.

On examination, he burst out into loud laughter continuously. He had a fixed but happy expression. There was considerable dribbling of saliva from the mouth. He walked with a shuffling, wide-based gait which started slowly and became a run with a tendency to walk on his toes after the first few steps. There was a generalised attitude of mild flexion. His speech was very monotonous and soft. He could not stand comfortably and the least movement caused a tendency to fall backwards. There were fine tremors of the outstretched hands, and generalised weakness of all four limbs with normal tone. The reflexes were brisk in the upper limbs but exaggerated in the lower ones. The abdominals were present, the plantars were flexor.

General examination revealed slight pallor of the mucosa and evidence of bronchospasm. The blood pressure was 114/88. The blood count showed an eosinophilia of 29 per cent. The Hb was 14 gms. per cent. The chest X-Ray was normal.

Patient No. 16. *S.A.—male,* 27 (*mine No.* 1).

Examined on 15/7/1959.

History : The patient worked as a loader for the first 6 months and then became a dry driller for 2 years. He has been off work for a year. The history started about a year ago and he gave up work almost immediately after the onset of symptoms. Tremors of the body were first noticed. He found difficulty in holding the machine and occasionally fell down while drilling.

A little later, he developed difficulty in walking. On giving up work, the condition became stationary. He also had considerable asthenia, unusual excitability, insomnia, occasional bouts of laughter, muscle cramps and it was reported that his general behaviour in the house had changed. He was light-hearted and irresponsible.

Examination : There was a tendency to spasmodic laughter without any crowing sound. He had an expressionless face. There was only a slight shuffling in his gait. His voice was forceful but his speech was slight and scanty. There was some amount of weakness of the limbs with normal tone. The reflexes were normal, the abdominals were present and the plantars were flexor. The blood pressure was 120/64 and the blood count showed an eosinophilia of 35 per cent. The Hb was 8.5 gms. per cent. The chest X-Ray was normal.

Patient No. 18. *K.N.—male,* 20 (*mine No.* 1)

Examined on 15/7/1959.

The patient was a loader for 5 months and a dry driller for 6 months. He became a wet driller for 15 days just prior to examination. His complaints started six months ago with generalised fatigue, asthenia, somnolence, a tendency to occasional laughter, clumsiness of movements leading to dropping of household articles very frequently, a tendency to fall backwards and occasional giddiness.

Examination : The only significant finding was marked retropulsion, out of all proportion to the other manifestations of the disease which were absent in this case. There was only a slight generalised asthenic weakness of all four limbs. The deep reflexes were normal, the plantars were flexors. The bood pressure was 110/80. The blood count showed an eosinophilia of 32 per cent. The Hb per cent was 13.5 gms. The chest X-Ray was normal.

Patient No. 19. *J.K.—male,* 25 (*mine No.* 1).

Examined on 15/7/1959.

The patient was a loader for 6 months and a dry driller for one year. He has given up work for the last three months on account of his symptoms. The history started with headaches, giddiness, cramps in the legs and difficulty in walking for about three months. He also had slight lumbar pains and at most times he was inclined to be depressed although he laughed excessively in company. He had noticed some tremors of his

upper limbs and tended to fall backwards whilst squatting. He found it difficult to walk easily and thought that there had been some stiffness of the legs recently.

Examination : He had a fixed expressionless face, and no pathological laughter. His gait was normal, except for a slight hesitancy. The speech was normal. His voice was slow. The power in the limbs was slightly diminished and the tone was normal. The deep reflexes were normal and equal. The plantars were flexor. The blood pressure was 110/68. The blood count showed an eosinophilia of 9 per cent and the Hb per cent was 9 gms. The chest X-Ray was normal.

Patient No. 797. *G.H.—male,* 40 (*mine No.* 9).

This patient has worked as a driller and also as a miner for 19 years; he did 2 years' dry drilling at the beginning of his career. He was still working when examined. The symptoms started 4 to 5 years ago. He had difficulty in walking with a tendency to fall easily, specially on slopes. He complained of anorexia, asthenia, insomnia, mental irritability and muscle cramps. He thought his condition had been getting worse gradually. There was a history of temporary insanity 6 years ago.

History : as given by his nephew: The symptoms started 5 years ago. The patient's voice had become inaudible and his speech indistinct. He could not walk properly. He became mentally irritable and morose but not talkative. He used to keep to himself. He was reported to laugh easily at small things for a year now.

Examination : His general health was good. His mental state was normal. He rarely smiled and there was no laughter. He looked depressed and his face was emotionless. His voice was thick but soft; he could not shout, and his speech was indistinct, monotonous and slurred. His gait was slow and spastic, but there was no cock-walk, though it was a little wide-based. Retropulsion was evident. He did not fall on being pushed backwards. He could not walk on a straight line and rotation was slow and jerky; but he could sit and get up quickly. There was no true incoordination, but his movements were slow. There was an asthenic type of weakness in the upper limbs. The muscle tone was normal. There were no tremors. The lower limbs showed a mild weakness with minimal spasticity. Ankle clonus was present. The heel-knee test was slowly performed. The reflexes were brisk in the upper limbs; exaggerated in the lower limbs; the abdominals were present and the plantars could

not be elicited. There were no sensory changes. Clubbing was present but there was no cyanosis or any bronchial signs. He had mild pigmentation of the hard palate.

Investigations.

1. Blood	RBC	4·65 mill/ cmm.
	WBC	5,800/ cmm. P 63, E 12, L 20, M 5.
	Hb	15 gms. %
	PCV	44·5
	VDRL & RMT	Negative.
	MCV	95 c/u/u
	MCHC	34%
2. Fundi	Normal. No corneal ring seen.	
3. Faeces	Ova of ankylostoma duodenale seen.	
4. Urine	Albumen and sugar absent. Microscopically normal.	
5. Sputum	Normal.	
6. I.Q. Test	Normal.	
7. X-Ray	Chest—scarring of the left upper zone due to old pleurisy. Skull—Normal. Lumbar spine—Osteoarthritic changes seen.	
8. Liver function tests ..	Total proteins	6·5 gms. %
	Albumen	3·7 gms. %
	Globulin	2·8 gms. %
	Alkaline phosphatase	12·1 K.A. Units
	Thymol turbidity	1 unit
	Icteric Index	6 units
	Van den Bergh	Negative.
9. Air encephalography	The ventricles were normal and no cortical atrophy was detectable.	
10. Cerebrospinal fluid ..	Manometry not done.	
	Proteins	30 gms. %
	Globulin	Not increased.
	Sugar	60 mgms. %
	Chlorides	720 mgms. %
	Cells	4 Lymphocytes.
	W.R.	Negative.
	Lange's Curve	0000000000
11. Serum Iron	153 micrograms %	
Serum Copper ..	102 micrograms %	
Serum Vit B_{12} ..	330 micrograms %.	
12. E.E.G. report ..	The EEG is normal except for a strikingly low voltage presenting a flat record throughout. During natural sleep the various normal phases of sleep changes were recorded, but the humps were very badly formed.	

13. Serum Manganese	..	1·40 microgm. in 5 mls.
Urine Manganese	..	1·15 microgm. in 10 mls.
Faecal Manganese		22·37 microgm. in 1 gm. of wet faeces.
Cerebrospinal fluid Manganese	.. ..	1·16 microgm. in 5 mls.
14. Bone Marrow	..	Marrow is cellular. M:E:: 1·5:1. Myeloid shows normal differentiation. Eosinophils are slightly increased. Plasma cells are within normal limits. Erythroid series is normoblastic. Magakaryocytes are slightly increased.

No treatment was given as the patient wished for immediate discharge from the hospital.

Patient No. 820—*M.T.* (*mine No.* 9).

He had been working as a driller and miner for 9 years and worked in dry drilling for 1½ years. Five years ago he developed extreme asthenia and then gradually developed mental derangement and irritability. He was easily disturbed by noise, could not concentrate at work, had insomnia, loss of appetite and used to laugh more than usual. There were no fits of weeping. He was not completely out of his mind. He was working at the time of examination.

Examination : The patient had a dull morose face, which was somewhat expressionless. His voice was low-pitched and soft. He answered only on repeated questionnaire, but there was no dysarthria. He had a broadbased gait, and walked more or less on his heels. There was no cock-walk. The tone was normal; there was no spasticity. Tremors were present. The deep reflexes were brisk all over, and ankle clonus was present. On general examination, pigmentation of the gum and hard palate was noticed. The Hb per cent was 14.5 gms. The chest X-Ray showed no abnormality.

Patient No. 821. *B.D.* (*mine No.* 9).

He has worked for 16 years in the mine. Four years ago he became a driller and worked for 7 months when weakness and unsteady gait appeared. He was taken off drilling in a month or two but the condition worsened during the next 6 months and then became static. His wife noticed the defect earlier, but none of his friends mentioned that they had noticed any change in him.

Examination : He had an impassive face but he did not appear morose. He showed a tendency to mild retropulsion and his gait was spastic but there was no cock-walk. He walked

with a slightly wide base. Gum pigmentation was marked. The other systems were normal. Hb per cent examination showed 14.5 gms. The chest X-Ray was normal.

Patient No. 825. *N.B.—male,* 35 (*mine No.* 9).

This patient had been working in the mines for 8 years; first as a dry driller and then as a wet driller for the last 5 years. He is still working, but for the last two years, he has been on the surface. When he was a dry driller, he noticed a difficulty in speech and walking. He was taken off work within 2 months of the onset of his symptoms; but his condition progressed slowly for a while and then became static. He complained of difficulty in going up and down slopes and of generalised asthenia. He found that his voice was low and he could not raise it. His speech, too, was indistinct. He said he laughed excessively at times, without any emotion.

Examination : The patient had a fixed face but was not morose or unduly depressed. There was no spasmodic laughter. His mental state was normal. The speech was low, monotonous and indistinct. He talked without much opening of his mouth. There was a slight attitude of generalised flexion, more marked in the trunk muscles. He had a spastic gait, but did not walk on his toes. The power and tone of the limbs were normal, but his movements were generally slow and clumsy. The upper limb reflexes were normal, but the lower limb reflexes were brisk. The abdominals were present and the plantars were flexor. The other systems were normal.

Investigations

1. Blood	RBC	5·5 mill/ cmm.
	WBC	5,600 /cmm. P 50, E 10, L 40, M 0.
	Hb	15·4 gms.%
	PVC	48
	VDRL & RMT	Negative
	MCV	87 c/u/u.
	MCHC	32%
	Reticulocytes	0·2%
2. Faeces	No ova or cyst seen.	
3. Urine	No albumen and sugar. Microscopic examination was normal.	
4. Sputum	No acid fast bacilli detected.	
5. I.Q. test	Within normal limits.	
6. Fundi	Normal. No corneal rings seen.	

7. X-Rays	.. ..	Skull—Normal. Chest — — — — Normal. Lumbar spine showed changes of chronic osteo-arthritis.
8. Liver function tests	..	Total proteins .. .. .. 7·0 gms. % Albumen .. .. 4·2 gms. % Globulin .. .. 2·8 gms. % Alkaline phosphatase .. .. 10·2 K.A. units. Thymol turbidity .. .. .. 3 units. Icteric index .. .. .. 5 units. Van den Bergh .. .. .. Negative
9. Serum Iron	.. ..	115 microgm. %
Serum Copper	..	59 microgm. %
Serum Vit. B_{12}	..	210 micromicrogm. %
10. Serum Manganese	..	10-6-1960 : Before EDTA—1 microgm. in 5 mls. 4-7-1960 : Immediately after EDTA—1·87 microgm. in 5 mls. (2 days after a course of Calcium EDTA orally 5 gms. daily for 10 days).
Before I.V. EDTA	..	13-3-1960 : 0·995 microgm. 19-8-1960 : 1·75 microgm. After 3 days of EDTA (2·5 gms. in 500 c.c. saline) 1·40 microgm. (23-8-60). After 6 days of E.D.T.A. 0·95 microgm. (25-8-1960). 10 days after E.D.TA. stopped 0·94 microgm. (6-9-1960).
Urine Manganese	..	Before EDTA 1·10 microgms. in 10 mls. 143 microgms. in 24 hrs. (1300 mls.). Immediately after EDTA 1·10 microgms in 10 mls. 112 microgms in 24 hrs. (1023 mls.).
Faecal Manganese	..	29·54 microgms. in 1 gm. of wet faeces (after EDTA).
Cerebrospinal fluid Manganese.		Before EDTA 1·60 microgm. in 5 mls. Immediately after EDTA, 2·20 microgm. in 5 mls.
11. Cerebrospinal fluid	..	Manometry not done. Proteins .. .. .. 25 mgms. % Globulins .. .. .. Not increased. Sugar .. .. 66 mgms. % Chlorides .. ..650 mgms. % Cells .. .. 2 lymphocytes. W.R. Negative Lange's curve 0000000000
12. Bone Marrow	..	Marrow is cellular. M:E: :7·5 Myeloid shows normal differentiation. Erythroid series suggestive of hyperplasia. Megakaryocytes are few, since plasma was diluted.

13. E.E.G. report	Low voltage recording in all areas except in the posterior temporal areas where it is normal. Alpha activity of good voltage (12 to 30 microvolts is for a large part of tracing. There is also 30 c.p.s. fast activity specially in the frontal epoches.

Treatment and progress : This patient was given 5 gms. of Calcium EDTA orally in two divided doses for 10 days. He made no improvement at all at the end of it. However, 8 weeks later Calcium EDTA was given intravenously, 2.5 gms. in 500 cc saline by drip method, daily for six days. Again no improvement in either his speech or facial expression was noticed. His limbs and gait being unaffected, no assessment of improvement of body tone was possible. After another 15 days, without drugs he was put on Parpanit (6.25 gms.), one tablet TDS increasing daily by one tablet TDS till 50 mgm. TDS dose was reached. He was continued for a time on this but made no improvement. Of course, Parpanit acts on the body tone and as this was normal to begin with no remarkable improvement could be expected. Parpanit rarely causes any change in a Parkinson's disease patient although it does improve the speech.

Patient No. 845. *A.H.—male* (*mine No.* 9).

He has been working as a miner for nearly 10 years, out of which for 4 years he has been a machine driller. He was suspended by the manager twice from dry drilling. Four years ago, while working as a driller, he developed pneumonia and then after a few months came off work with insomnia, lack of concentration, irrelevant talk and aimless wandering. He used to laugh or weep more than usual. He was off work for a period of nearly 2 years and then felt better and returned to duty. He was working at the time of examination.

Examination: No gross abnormality was detected in the central nervous system except for a mild spastic gait with increased tendon reflexes of the lower extremities. The muscle tone was slightly increased but power was more or less normal. There were no speech defects or facial changes. Tremors were absent.

The Hb percentage was 13.5 gms. The chest X-Ray showed numerous linear and reticular opacities. The lung pattern was normal. (ILO Classification Grade L).

Patient No. 870. *M.C.—male,* 43 (*mine No.* 9).

Examined on 23-3-1960.

He has been a miner and driller for 15 years. Four years ago he is reported to have gone completely insane while he was

employed underground and doing dry drilling. This lasted for about 2 years during which time he was off work. He could not concentrate, there was considerable disorientation and confusion, and he used to wander about aimlessly.

Examination: There was clinically nothing abnormal in the central nervous system except for brisk tendon reflexes and unsustained ankle clonus. There were no speech defects, facial changes or abnormality of gait. The Hb estimation was 15.5 gms. per cent.

He was thought to be suffering from a mild form of manganese intoxication which had improved after removal from exposure.

Patient No. 878. *T.B.—male,* 34 (*mine No.* 9).

Examined on 23-3-1960.

This man had worked for 7 years in the mines for the first two years as a loader, then as a hand-driller for 4 years and as a machine driller for the last year.

While he was working as a driller he developed pneumonitis (cough, pain in the chest, etc.). A little later he noticed difficulty in going up and down the mines and complained of headache. He was taken off work at that stage. Personality changes with euphoria and excessive laughter, were noticed subsequently.

Examination : His memory was normal. He looked depressed and his face was mask-like. His speech was indistinct and he had a low monotonous voice. There was pigmentation of the gums and excessive dribbling of saliva.

The gait was shuffling with marked propulsion and very marked retropulsion. The power was diminished in the lower limbs and tone was normal. Coarse tremors of the tongue and hand were present. The tendon reflexes were diminished and plantars were flexor. The Hb per cent was 11.00 gms.

Patient No. 879. *A.M.—male,* 30 (*mine No.* 9).

Examined on 23-3-1960.

He had worked as a miner and machine driller (mostly dry drilling) for 3 years, but was off work for 2 years. His complaints started 4 years ago with extreme asthenia, insomnia, irritability and lack of concentration at work. Later, he developed weakness of the legs and difficulty in speech.

Examination : He was very emotional (there was excessive weeping while narrating his story). Except for exaggerated lower limb reflexes and unsustained ankle clonus, no neurological signs were found. The plantars were flexor. The Hb. per cent was 9.5 gms. He was accepted as a case of mild manganese intoxication recovering after removal from dust exposure.

Patient No. 880. *Y.P.—male,* 35 (*mine No.* 9).

The patient had been working as a loader for 3 years, then as a machine and hand driller for 4 years. Three years ago he developed asthenia, insomnia, muscle cramps and difficulty in walking specially up and down the slopes. He also complained of a tendency to weep or lough on the least provocation. The symptoms have progressed gradually.

Examination : He was poorly built and anaemic. He had a mask-like depressed face. His speech was normal. There was marked spasticity in his gait but propulsion and retropulsion could not be demonstrated (due to his inability to walk). The power was diminished in the lower limbs with some increase in the tone. The reflexes were grossly exaggerated and the plantars were equivocal.

In view of this symptomatology, this was considered to be a positive case of manganism in spite of the greater prevalence of pyramidal signs.

Patient No. 881. *F.M.—male,* 48 (*mine No.* 9).

He had been working as a loader for 2 years, then as a hand driller for 9 years and as a machine driller for the last year. The symptoms started 4 years ago with difficulty in walking. He also felt easily fatigued and mentally irritable. There was excessive weeping and somnolence. His finger movements gradually became clumsy. He was off work since the onset of symptoms, but has made no improvement.

Examination : There was apathetic behaviour with poor concentration and he had a dull, expressionless face. There was dribbling of saliva and coarse tremors of the tongue. The speech was low and monotonous with poor articulation. The gait was shuffling in nature with marked propulsion and retropulsion and a tendency to fall easily. The power was diminished in all the four limbs. The tone was normal. The deep reflexes were normal and the plantars were flexor. The Hb per cent was 11 gms.

Patient No. 883. *M.T.—male,* 42 (*mine No.* 9).

The patient had been working as a miner and a driller for 22 years, underground for 20 years and on the surface for the last 2 years. He noticed a weakness of his lower limbs about 5 years ago with a tendency to fall. He also had a lumbar pain, asthenia, somnolence, and at times, wept excessively. There was also some weakness of the arms. He felt that there was some improvement in his condition after stopping underground work.

Examination : He was ill-nourished and pale. He was mentally elated. His face and speech were normal. His gait was shuffling in nature with a cock-walk; marked propulsion and retropulsion were noticeable. The power of both limbs was was normal. The tone was slightly increased with brisk tendon reflexes. The plantars were equivocal. The Hb was 13 gms. per cent.

Patient No. 884. *C.G.—male,* 30 (*mine No.* 9).

The patient had been a machine driller for 4 years and was off work for the last two years. About 5 years ago he developed a tendency to fall easily while walking or squatting. This was followed by indistinct speech, asthenia, excessive laughter or weeping, somnolence, muscle cramps and mental irritability. He also noticed clumsiness of fine movements of the hands.

Examination : His nutritional state was poor. He had an expressionless dull face with very occasional crowing laughter. He had a low muttering speech with slurring. His gait was hesitant with a cock-walk. There was marked propulsion and retropulsion and he would easily fall backwards on squatting. There was slightly diminished power in the lower limbs with brisk tendon reflexes. The plantar response was flexor. The Hb per cent was 14 gms.

Patient No. 889. *S.M.—male,* 40 (*mine No.* 9).

History : The patient was working as a miner and a driller for 15 years. He left work for a year after the first four years, and then, resumed duty. About 7 years ago, he developed weakness of the legs, which progressed slowly. His condition deteriorated initially for 2-3 years, and then became static. Four to five years ago, he became completely insane, and this lasted for a year or so. Since the last 2 years he has developed a cough and had occasional haemoptysis. Now, for a year, there has been asthenia, difficulty in going up and down the slopes with frequent falls, excessive laughter, muscle cramps and mental irritability.

Examination : The patient had a depressed face but it was not mask-like. His mental state was normal, though his level of intelligence was poor. His speech was normal. He had an unsteady moderately spastic gait. There was slight propulsion and retropulsion. On squatting, he fell backward. The power and tone were normal; and there were no tremors. The reflexes were exaggerated in both the upper and lower limbs and an ankle clonus was elicited. The plantars were extensors and the abdominals were present. On general examination, there was evidence of emphysema and chronic bronchitis.

Investigations :

1. Blood	RBC	5·15 mill/cmm.
	Hb	14·2 gms.%
	WBC	6,800/cmm. P 5, E 8, L 37, M 4.
	PCV	47%
	VDRL & RMT	Negative
	MCV	91 c/u/u
	MCHC	30%
	Reticulocytes	0·2%
2. Urine	No albumen or sugar detected. Microscopically normal.	
3. Faeces	No ova and cysts seen.	
4. Sputum	No A.F.B. detected.	
5. Fundi	Normal—There was no evidence of a metallic ring in the cornea on slit lamp examination.	
6. I.Q. test	Showed normal average intelligence from the group from which he comes.	
7. X-Rays	Chest—Normal Skull—Normal Lumbar spine—Early osteoarthritic changes seen.	
8. Liver function tests :		
	Total proteins	6·3 gms. %
	Albumen	3·7 gms. %
	Globulin	2·6 gms. %
	Alkaline phosphatase	9·4 K. A. units.
	Thymol turbidity	2 units
	Icteric index	2 units
	Van den Bergh	Negative
9. Serum Iron		180 microgm. %
Serum Copper		46 microgm. %
Serum Vit. B_{12}		115 micro-microgm. %

10. Serum manganese	..	Before EDTA 1·10 microgms in 5 mls. Immediately afterEDTA 2·15 microgms. in 5 mls. 2 months afterEDTA 1 microgm in 5 mls.
Urinary manganese	.. ..	Before EDTA 1·60 microgms in 10 mls. 144 microgms in 24 hrs. (900 mls.). Immediately afterEDTA 1·25 microgm in 10 mls. 142 microgms in 25 hrs. (1,136 mls.).
Faecal manganese	..	25·90 micorgms in gm of wet faeces (after EDTA).
Cerebrospinal fluid manganese before EDTA.		1·15 microgms in 5 mls. Immediately after EDTA 3 microgm in 5 mls.
11. Cerebrospinal fluid	..	Manometry not done. Proteins .. .. 40 mgms. % Globulins .. .. .. Not increased Sugar .. .. 63 mgms. % Chlorides .. .. 730 mgms. % Cells .. .. 1 lymphocyte. W.R. .. .. Negative Lange's curve 0000000000
12. E.E.G. report	..	(1) Poorly modulated alpha activity improving on hyper-ventilation. (2) Very low voltage, flat recording at 5 to 15 microvolts. The dominant rhythms are 10—12 c.p.s. (low alpha index), plus 18 c.p.s. and some 7 c.p.s. activity. (3) Very little inter areal difference.
13. Bone marrow	..	Marrow is cellular. M:E:E:1:1 Myeloid shows normal differentiation.Erythroid series is normoblastic. Megakaryocytes are present and active.

Treatment and Progress : This patient was given only Calcium EDTA by mouth, 5 gms. in a day in two divided doses for 10 days. The patient felt subjectively better, and stated he could walk more easily. Our examination revealed the same degree of defect of gait, retropulsion and propulsion, and the same tendency to fall backwards on squatting. After nearly 2 months' drug free interval he was put on parpanit (6.25 mgm.) one tablet three times a day, increasing daily by one tablet T.D.S. till 50 mgm. T.D.S. This was continued till he was discharged home 10 days later. On Parpanit the tone in his legs was diminished and his walking easier and less spastic. However, the improvement was not dramatic and it was felt that whilst he was in the wards for nearly three months there was slight but steady improvement in his gait even before the drugs were given.

APPENDIX II

Histories of cases of Primary Lateral Sclerosis.

Case No. 8. *A.W.—male,* 27 (*mine No.* 1).

The patient started working as an underground driller, doing mostly dry drilling four years prior to our examination; he remained in that occupation for three and a half years when he gave that up and became a loader for 3 months due to his physical handicap. For six months he has been off work. He first noticed difficulty in walking and weakness of his legs three years ago. This has gradually led to an increasing handicap. There were no sensory emotional or sphincter disturbances. No definite history of excessive consumption of 'Kesri dal' could be obtained.

Examination revealed moderate pure motor paraplegia with spasticity, exaggerated deep reflexes and ankle clonus. The abdominal reflexes were present, the plantar reflexes were flexor. No sensory loss was detected. The upper limbs and cranial nerves were normal. No pathological laughter or Parkinsonian faces were evident. The blood examination revealed an eosinophilia of 15 per cent and the Hb. per cent was 15.25 gms. The chest X-Ray was normal.

Patient No. 838. *D.S.—male,* 30 (*mine No.* 9).

This patient had been working as a driller for the first 8 years and as a watchman for the last 4 years. He gradually noticed difficulty in walking about 5 years ago. There were no sensory or bladder disturbances. He took very little 'Kesri dal' in his food.

Examination : He had a moderately severe spastic paralysis with a scissor-gait. All the deep reflexes specially those in the lower limbs were exaggerated. The abdominal reflexes were absent and the plantars were extensor. His emotions, speech, facial expression and upper limbs were normal. The Hb. estimation was 13.5 gms. per cent. The chest X-Ray was normal.

Patient No. 847. *S.M.S.—male,* 50 (*mine No.* 9).

This patient has been working as a miner and hand driller for 23 years and as a machine driller for the last 2 years. He had difficulty in walking for over 20 years. The patient came from a district where lathyriasis is common but gave no history of intake of 'Kesri or Lakhori dal'.

Examination : He had a gross spasticity of the lower extremities with a scissor-gait. His lower limb deep reflexes were grossly exaggerated with bilateral plantar extensor responses. He also had an ankle clonus on both sides. There were no emotional, speech, facial or any upper limb disturbances. The Hb per cent estimation was 15 gms. The chest X-Ray was normal.

Patient No. 890. *D.K.—male, 46 (mine No.* 10).

He has been working as a miner and driller for 17 years. He also gave a history of taking 'Lakhori dal' for a prolonged period of over 5 to 6 years. He complained of weakness of his legs and difficulty in walking for over 6 years.

Examination : He showed signs of pyramidal tract involvement with a mild spastic gait with increased tendon jerks in the lower extremities and unsustained ankle clonus. The plantars were equivocal.

There was no personality change, speech defects, tremors or rigidity. The Hb estimation was 11.5 gms. per cent.

Patient No. 891. *P.J.—male, 48 (mine No.* 10).

He has been working as a miner for 8 years and a boulder-crusher for 5 years. He also gave a dietetic history of taking 'Lakhori dal' for a prolonged period when he was at Seoni 20 years ago. He had stiffness of the lower extremities and difficulty in walking for over 20 years, before he actually joined the mines.

Clinically, he had a mild spastic gait with marked increase in the tendon reflexes of the lower extremities and an unsustained ankle clonus. The plantars were equivocal. The Hb estimation was 13 gms. per cent.

Patient No. 892. *G.T.—male, 45 (mine No.* 10).

This patient comes from Seoni district where lathyrism is prevalent and he gave a history of taking 'Lakhori dal' for a prolonged period of over 5 years. He gave a history of stiffness in his legs with some gradually progressive weakness for over 16 years.

Examination : The power in the lower extremities was somewhat diminished but the tone was increased. He had a spastic gait with a marked increase in tendon reflexes and an unsustained ankle clonus. The plantars were equivocal. Chest X-Ray showed evidence of pleural thickening. (P.L. I.L.O. Classification). The Hb was 11 gms. per cent.

Patient No. 893, *P.A.—male,* 46 (*mine No.* 10).

This patient comes from Seoni district and gave a history of consuming 'Lakhori dal' 15 years ago at irregular intervals when he was in Seoni before he joined the mines. He complained of stiffness of his legs and difficulty in walking for over 10 years.

Examination : He had a spastic gait, with weakness in his legs and increase of tendon reflexes. The plantars were equivocal. The Hb was 10.5 gms. per cent.

APPENDIX III

Determination of Manganese in Clinical Material.

(Durgakari, U.S., Bettary, R.A. and Jhala, H.I.,

Haffkine Institute, Bombay).

Method :

A sample containing approximately 1—15 microg. of manganese is either weighed or measured out in a crucible, first heated gently to dryness and then vigorously to redness when the sample forms an ash. On cooling, 3 ml. of conc. nitric acid (free from oxides of nitrogen) are added followed by 10 ml. of distilled water. This is then gently heated on a low flame so that it slowly evaporates to dryness without spurting, the crucible being kept only partly open by means of a lid at the last stage of evaporation when there is a possibility of spurting. This is repeated twice more to affect complete removal of traces of chloride, if any, as it hinders the oxidation reaction. 4 ml. of conc. nitric acid and 10 ml. of distilled water are then added and the residue is made to dissolve completely in the acid. The solution is then transferred to an evaporating dish and 0.2 g. of sodium bismuthate is added and the solution is boiled for about 2 minutes when the whole of the sodium bismuthate decomposes leaving a clear solution. This is then cooled below 30° C. Weise and Johnson recommend that 0.3 g. of sodium bismuthate is to be added to the solution in the dish at this stage, mixed thoroughly and after allowing to stand for a few minutes it should be filtered through shredded asbestos, to remove the bismuth oxide, directly into a graduated flask containing two drops of benzidine previously added. The solution is made to volume and the readings are taken. We found that some of the sodium bismuthate did escape through asbestos seriously affected the colour development. Filtration through analytical grade filter paper resulted in the loss of permanganate and very poor recovery of manganese was noted. In our procedure, the cooled solution from the evaporating dish is transferred to a 50 ml. volumetric flask. To this is added 0.3 g. of sodium bismuthate and the flask is shaken well to ensure thorough mixing. It is made to volume and shaken well. About 20 ml. from this solution are transferred to a 50 ml. centrifuge bottle and it is allowed to stand for 2½ hours. It is then centrifuged and from the clear supernatent fluid 10 ml. are pipetted out and transferred to a cuvette in which are previously added 2 drops of

benzidine reagent. The colour develops within 3—5 minutes and is read on a Coleman Spectrophotometer at 420 mu. A blank is carried out with distilled water.

Reagents :

The materials used are of a very pure quality.

(1) *Benzidine* : This is crystallised from 70 per cent alcohol first, redissolved in 70 per cent alcohol, treated with charcoal when hot and recrystallised. This is once again crystallised from Benzene. A 1.0 per cent solution is prepared in 5.0 per cent acetic acid and stored in a dark coloured bottle.

(2) *Nitric Acid* : This is of the analar grade, free from oxides of nitrogen.

(3) *Sodium Bismuthate* : Sodium bismuthate used is of the extra pure quality. In spite of that it contains traces of manganese (not more than 0.0005 per cent). As the same quality compound was used for the standard as well as the experimental samples, the presence of manganese did not hinder the values.

Tests :

A standard curve was obtained using known amounts of manganese as permanganate, which was treated with bismuthate and then with benzidine to form coloration and the optical density was measured at 420 millimicron wavelength on Coleman Spectrophotometer.

To test the applicability and the realiability of the method, known quantities of manganese, in the form of a solution of chemically pure manganese chloride, were passed through the entire process of charring, digesting thrice with conc. nitric acid to remove chloride completely, oxidising with sodium bismuthate and subsequent colour development. The intensities of the colours measured were found to be in agreement with the standard curve prepared directly from permanganate, indicating full recovery. Next, known amounts of manganese in the form of manganese chlorides, were added to samples of urine to see the recovery and it was also seen that added manganese was fully recovered. The following table shows the results obtained and confirms the reliability of the procedure :

No.	Particulars of Sample	Extra Mn. added in mcg.	Total Mn. found mcg.	Recovery of extra added Mn. in mcg.	% Recovery
	$MnCl_2$ soln. containing 2 mcg of Mn.	nil	2·1	nil	105·0

2. $MnCl_2$ soln. containing 4 mcg. of Mn. ..	nil	4·1	nil	102·5
3. $MnCl_2$ soln. containing 6 mcg. of Mn.	nil	6·06	nil	100·8
4. Urine (10 ml.) of Patient No. 7584	nil	0·9	nil	
5. Urine (10 ml.) of Patient No. 7584†	2·0	2·91	2·01	100·5
6. Urine (10 ml.) of Patient No. 7255	nil	2·29	nil	
ine (10 ml.) of Patient No. 7255†	2·0	4·20	1·91	95·5

hole Blood :

When samples of whole blood were processed as above, in some cases the colour development was not rapid as seen in other samples. The intensity went on increasing over a period of about 20 minutes and then attained a maximum value. Because of this uncertainty, whole blood could not be taken for assay. Recently a trial of whole blood without and with added manganese has revealed that when maximum intensity has been attained after a long interval then the recovery is almost full It seems therefore that the whole blood can also be used for assay if sufficient time (up to 20 minutes) is allowed for colour development. This is being confirmed by further work and thereafter whole blood can also be taken for assay.

Trials were taken to see whether external manganese got introduced during the process of removal of CSF or blood through the needle of the syringe. It was observed that the sample of distilled water passed through the needle gave the same result as that of the blank indicating thereby that no manganese is contributed by the needle during the process of removal of the samples.

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